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ERRATA.

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48, line 26, for *M. danica* read *E. danica.*

155 „ 13 from bottom, *for* oae *read* one.

167 „ 2 „ „ *for* hewever *read* however.

212 „ 26, for *rotundata*, Poiret, read *leucostoma*, Millet.

219 „ 9 from bottom, for *naidina* read *naiidina.*

230 „ 4 „ „ *fustifera* read *fustifera.*

236 „ 13, for *naudina* read *naiidina.*

254 „ 3. for STYELOPSIS read STYELA.

„ „ 15, 18, 22, for *Styelopsis* read *Styela.*

293 „ 15 from bottom, *for* 63 *read* 64 pt. 3.

404 „ 17, for *Haloporella* read *Holoporella.*

THE JOURNAL

OF

THE LINNEAN SOCIETY.

(ZOOLOGY.)

Some Collections of the Littoral Marine Fauna of the Cape Verde Islands, made by CYRIL CROSSLAND, M.A., B.Sc., F.Z.S., in the Summer of 1904. —BRYOZOA. By ARTHUR WM. WATERS, F.L.S., F.G.S.

(PLATES 1–4, and 2 Text-figures.)

[Read 16th November, 1916.]

THE collections, kindly submitted to me by Mr. Cyril Crossland, were made from Boa Vista, Cape Verde Islands (1); from underneath a coal-lighter in St. Vincent Harbour, marked (2); dredged, in 10 fathoms, in St. Vincent Harbour from a bottom of foraminiferous sand and nullipore nodules—also clinkers, &c. (3).

This communication completes the description of Crossland's tropical collections of Bryozoa. Two papers have been published by the Linnean Society on the Red Sea material, and two by the Zoological Society on that from British East Africa and Zanzibar. These last are referred to as "Bry. from Zanzibar."

Specialists have already described parts of the collections in the pages of this Journal and in those of the Zoological Society's 'Proceedings.' This Cape Verde collection was made with the aid of a grant from the Carnegie Trustees.

My plan, for a long time, has been practically to complete any paper by comparison of my own collections, and then to check my results in the

Natural History Museum, especially regarding types; and I have again to thank Mr. Kirkpatrick for giving me facilities on these periodical visits.

The literature on the Bryozoa of the neighbouring seas includes:—

SMITT.—"Floridan Bryozoa," Kongl. Svenska Vetensk.-Akad. Handl. vols. x. & xi. 1872–73.

BUSK.—"On some Madeiran Polyzoa," Quart. Journ. Micr. Sc. vols. vi., vii. 1858–1859; "Catalogue of Polyzoa collected by J. Y. Johnson at Madeira," *op. cit.* vol. viii. 1860–1861.

HINCKS.—"The Madeiran Polyzoa," Ann. Mag. Nat. Hist. ser. 5, vol. vi. 1880, p. 69.

JOHNSON, J. YATE.—"New Cyclostomatous Bryozoa found at Madeira," Ann. Mag. Nat. Hist. ser. 6, vol. xx. 1897, p. 60.

WATERS.—"Bryozoa from Madeira, &c.," Journ. R. Micr. Soc. 1899, pp. 6–16.

NORMAN.—"Polyzoa of Madeira," Journ. Linn. Soc., Zool. vol. xxx. 1909, p. 275.

OSBURN, R. C.—"The Bryozoa of the Woods Hole Region," Bull. Bur. of Fisheries, vol. xxx. 1912; "Biological Survey of the Waters of Woods Hole and Vicinity," *op. cit.* vol. xxxi. pt. 1, p. 102, pt. 2, p. 595. 1913; "The Bryozoa of the Tortugas Islands, Florida," Publ. 182, Carnegie Inst. of Washington. 1914.

Points of Special Interest.

(1) The discovery of *Tubulipora* (*Proboscina*) *Lamourouxii*, Audouin, which has never been understood, so that the generic name *Proboscina* has been incorrectly used by some authors for forms allied to *Stomatopora*: p. 31.

(2) The way in which certain species of *Schizoporella* grow in layers, with the younger layer taking definite positions, frequently passing over the opercula. Together with this, the closures of the Cheilostomata are considered: pp. 15 & 16.

(3) The spines surrounding the zoœcia of *Cribrilina radiata*, Aud., and the formation of the zoœcia are considered: p. 11.

(4) A very interesting *Lichenopora* with confluent zoaria is more fully described. Some subcolonies are multiserial, others uniserial, and it is difficult to decide whether they should be considered as one or two species: p. 33.

(5) Several points relating to the classification of *Crisia* are dealt with: p. 24.

The collections made by Mr. Cyril Crossland consist of 45 species or varieties, of which 25 were already known from the Atlantic, 16 are British, 24 Mediterranean, and probably 17 are Australasian. Besides these, a list of 41 species already described from the Cape Verde Islands is given.

Table of Distribution from West to East.

	Page.	Atlantic *.	British.	Mediterranean.	Red Sea.	Indian Ocean.	Ceylon.	Australasian.	Fossil.	
Aetea recta, Hincks	5	+	+	+	...	...	...	+		
Bugula dentata, Lamx.	5	...	...	...	...	...	...	+	...	Japan, E. Africa, Amboina, Lifu, Amirante, Azores, Canary Is., S. Afr.
Scrupocellaria Bertholletii, Aud.	5	+	...	+	+					
„ *Macandrei*, Busk	6	+	...	+	...	+	...	+	...	Zanzibar.
„ *tridentata*, sp. nov.	7	...	...	...	...	...	...	...	...	
Beania hirtissima, Heller	8	+	...	+	...	...	...	+		
Membranipora tenuirostris, Hincks	9	+	+	+	...	...	...	+	+	
„ *curvirostris*, Hincks	9	..	+	+						
„ *quadricornuta*, sp. nov.	9	...	...	...	...	...	...	...	...	
Cribrilina radiata, Moll	10	+	+	+	...	+	...	+	+	Mauritius, Brazil.
Thalamoporella Rozieri, Aud	13	+	+	+	+	+	+	+	+	
Schizoporella unicornis, Johnst.	14	+	+	+	+	...	+	...	+	Japan.
„ *spongites*, Pallas	16	+	...	...	...	...	+			
„ *oligopus*, Robertson	18	...	...	...	...	...	...	...	...	California.
„ *trichotoma*, sp. nov.	19	...	...	...	...	...	...	...	...	
Osthimosia avicularis, Hincks	19	...	+	+	...	+	...	...	+	
Hippothoa distans, MacG.	20	...	+	+	...	+	+	+	+	S. Africa.
„ *divaricata*, Lamx.	20	+	+	+	...	+	...	+	+	S. Africa.
„ *hyalina*, Linn.	20	+	+	+	...	...	...	+	+	
Arthropoma Cecilii, Aud.	20	+	+	+	+ ?	+ N. S.	+	+	+	
Chorizopora Brongniarti, Aud.	21	+	+	+	...	...	...	+	+	
Smittina trispinosa, var. *protecta*, Th.	21	...	...	...	+	N. +	+			
„ *tropica*, Waters	21	...	...	...	+					
Lepralia cucullata, Busk	21	+	...	+	+	...	...	...	+	California.
„ *peristomata*, Waters	21	+								
Schizotheca fissa, Busk	22	...	+	+						
Holoporella pusilla, Smitt	22	+								
„ *aperta*, Hincks	23	+	...	...	+					
Microporella ciliata, Pallas	23	+	+	+	+	+ N.	+	+	+	Japan.
Adeonella contorta, Mich.	23	+	...	...	+	...	...	...	...	Brazil.
Crisia tubulosa, Busk	26	+	..	+						
„ *denticulata*, var. *verdensis*, nov.	27	...	...	...	...	...	...	...	...	
„ *sigmoidea*, Waters	29	...	...	+						
„ *vincentensis*, sp. nov.	29	...	...	...	...	...	...	...	...	
Tubulipora pulchra, MacG.	30	...	...	...	...	...	...	+	...	S. California.
„ *Lamourouxii*, Aud.	31	...	...	...	...	...	...	...	...	
„ *incrassata*, Smitt.	32	...	...	+						
Lichenopora irregularis, Johnson	33	+								
„ „ var. *composita*, nov.	38	...	...	...	...	...	...	...	...	
Flustrella hispida, Fabr.	38	...	+							
Amathia tortuosa, T. Woods	39	...	...	...	+	...	...	+		
„ *Vidovici*, Heller	41	+	...	+	...	...	...	...	...	Roscoff, B.E. Africa.
Zoobotryon pellucidum, Ehr.	41	+	...	+	+	+	...	+		
Bowerbankia pustulosa, var. *alternata*, nov.	41	...	...	...	...	...	...	...	...	
Barentsia discreta, Busk	42	+ N. S.	...	...	...	...	...	...	...	S. Pacific; Cape Horn.
Pedicellina cernua, Hincks	43	+	+	+	...	...	...	+		

* Previously known from the Atlantic.

Busk described a few s[illegible] Islands in the 'Challenger' Reports, also a few in his British Museum Catalogues, and Calvet described a considerable num[illegible] Travailleur' et du 'Talisman'"; so that the following are also known from the locality. A few species are omitted where there was doubt about the determination.

	Atlantic.	British.	Mediterranean.	Red Sea.	Indian Ocean.	Ceylon.	Japan.	Australian.	Fossil.	
Caberea ligata, Calv.	...	...	...	...	...	...	...	...	...	
Cellaria biseriata, Maplestone	...	...	...	...	...	...	...	..	+	
Beania magellanica, Busk	+ N. S.	...	+	...	...	...	+	+	...	South Africa, South America.
Membranipora patellaria, Moll.	+	...	+	...	...	...	...	+		
,, *bellula*, Hincks	...	...	...	...	+	+	...	+		S. Africa, Amboina, Antarctic.
,, *cervicornis*, Busk	...	...	...	...	...	...	...	+	...	
,, *granulifera*, Hincks	+									
,, (?) *filum*, Jull.	...	...	...	...	...	...	...	...	...	
Onychocella angulosa, Reuss	+	...	+	...	...	...	...	...	+	
Setosellina Roulei, Calv.	...	...	..	...	...	...	...	...	...	
? *Schizotheca Talismani*, Calv.	...	...	...	...	...	...	...	...	...	
Smittina cervicornis, Pallas	...	...	+							
,, *jacobensis*, Busk	...	...	...	...	...	...	...	+	...	S. America, Marion Isl.
Porella lævis, var. *subcompressa*, Busk	...	...	...	...	...	..	...	+		
Trypostega venusta, Norman	+	+	...	...	+	...	...	+	+	Lifu, Mauritius.
Haswellia alternata, Calv.	...	...	...	...	...	...	...	...	...	
Porina borealis, Busk	+	...	...	...	...	...	...	...	...	N. Europe.
Lepralia brancoensis, Calv.	...	...	...	...	...	...	...	...	...	
,, *Poissonii*, Hincks	+	...	+	...	+	+	+	+	+	China, Tahiti, Mauritius, Zanzibar.
Ichthyaria avicularia, Calv.	...	...	...	...	...	...	...	...	...	
Mamillopora simplex, Kosch. (*Mamillopora Smittii*, Calv.)	...	...	..	...	...	...	...	...	+	
,, *Edwardsi*, Jull.	+									
? *Myriozoum strangulatum*, Calv.	...	...	...	...	...	...	...	...	.	
Retepora Imperati, Busk	...	...	+							
,, *ramulosa*, Calv.	...	...	...	...	...	...	...	...	...	
Cellepora intricata, Calv.	...	...	...	...	...	...	...	...	...	
Cupularia Oweni, Gray	+	...	+	...	...	...	...	...	+	
,, *umbellata*, Def.	+	..	...	...	...	...	...	...	+	
Adeona Heckeli, Reuss. (*Microporella violacea*)	+	+	+	...	...	...	...	+	+	
Adeonella insidiosa, Jull.	+									
Crisia ramosa, Harmer (*elongata*, Norm.)	...	+	+	+						
,, *conferta*, Busk	+									
,, *tenella*, Calv.	...	...	...	...	...	...	...	...	...	
Entalophora raripora, d'Orb.	+	+	+	...	...	...	...	+	+	
,, *reticulata*, Calv.	...	...	...	...	...	...	...	...	...	
,, *subverticillata*, Calv.	...	...	...	...	...	...	...	...	...	
Idmonea atlantica, Forbes	+	+	+	...	...	...	+	..	+	Kerguelen, Cape Horn.
Filisparsa superba, Jull.	+	...	...	...	...	...	...	...	..	S. Pacific?
**Hornera brancoensis*, Calv.	...	...	...	...	...	...	...	...	...	
Stomatopora granulata, M.-Edw.	...	+	+	...	...	...	...	...	+	Magellan, Tristan da Cunha.

* *Hornera eburnea*, Calvet, is mentioned by Calvet from Cape Verde Islands. In 'Bryozoa from Zanzibar," Proc. Zool. Soc. 1914, p. 836, I said it was doubtful why it was placed with *Hornera*, and since then Prof. S. J. Hickson has shown that it is (*Stylasterina*) Hydrocoralline.

AETEA RECTA, *Hincks*.

BUGULA DENTATA (*Lamouroux*), *Busk*. (Plate 1. fig. 1.)

Achamarchis dentata, Lamx. Hist. des Polyp. corall. p. 135, pl. 3. fig. 3 (1816).

For synonyms see Miss Jelly's Catalogue, and add:—

Waters, "Bry. N. S. Wales &c.," Ann. Mag. Nat. Hist. ser. 5, vol. xx. (1887) p. 91, pl. 4. fig. 14; Kirkpatrick, Proc. R. Soc. Dublin, n. s. vol. vi. (1890) p. 614; Ortmann, "Die Japan. Bry.," Arch. f. Naturgesch. vol. i. (1890) p. 25, pl. 1. fig. 20; Philipps, "Rep. on the Polyzoa coll. by Dr. Willey, from the Loyalty Isl. &c.," Willey's Zool. Results, pt. 4, p. 443 (1899); Thornely, "Mar. Poly. of the Indian Ocean," Trans. Linn. Soc., Zool. vol. xv. (1912) p. 141; Calvet, "Bry. d'Amboine," Rev. Suisse de Zool. vol. xiv. (1906) p. 617, pl. 21. fig. 1; Norman, "Polyzoa of Madeira," Journ. Linn. Soc., Zool. vol. xxx. (1909) p. 285, pl. 36. fig. 3.

Krauss speaks of the zoarium being "bleifärbig und dunkelgraue"; Macgillivray says greenish or leaden colour; Busk says "ovicell blue" (but did he not mean to refer to the zoarium?); Kirkpatrick says "the zoarium is of a leaden-blue colour"; Miss Philipps, in her Loyalty Island paper, says "zoarium leaden-blue"; and Miss Thornely, in her Indian Ocean paper, says "ovicells not blue"; Calvet did not find any colour, but says that the specimen had been many years in spirit. No one, however, seems to have noticed the curious fact that the polypides and growing tissue are blue, looking just as if they had been stained, and in these Cape Verde Islands specimens it is a fairly bright blue. The specimens left in spirit have lost their colour, and one set of spirit-specimens were always without colour. A spectroscopic examination of this species would surely be interesting

The geographical range is very great, occurring in many places from Japan to the Cape Verde Islands.

There are about 14 tentacles.

Loc. Australia, New Zealand, Tasmania, S. Africa, Torres Str., 6–7 fath.; Lifu (*Thornely*), Amirante, 29–34 fath. (*Th.*), Amboina (*Calvet*), Sagamibai, Japan, 70 fath. (*Ortmann*), Madeira (*Norman*); Boa Vista, Cape Verde Islands, 20 fath., collected by Crossland.

SCRUPOCELLARIA BERTHOLLETII (*Audouin*), *Hincks*.

For synonyms see Waters, "Mar. Biol. of the Sudanese Red Sea, Bryozoa," Journ. Linn. Soc., Zool. vol. xxxi. (1909) p. 133, and add:—

Scrupocellaria Bertholletii, Norman, "Polyzoa of Madeira," Journ. Linn. Soc., Zool. vol. xxx. (1909) p. 283, pl. 36. figs. 1, 2; Calvet, Expéd. Sc. du 'Travailleur' et du 'Talisman,' Bryozoaires, vol. viii. (1907) p. 376.

There are some specimens closely attached to *Adeonella contorta*, Mich., with the creeping growth and attachment by radicles, as known in *S. reptans* (Linn.), Gray. On account of the resemblance of the two species I at one time spoke of *S. reptans*, var. *Bertholletii*.

There are some very large erect median avicularia, much larger than I have seen in any other specimens of *S. Bertholletii*. Hincks has mentioned the irregularity of the median avicularia, and this I can confirm from Mediterranean specimens, in which some parts are without them, and others have them fairly regularly.

Loc. Naples, Capri, Rapallo, Trieste, Suez, Madeira; Cape Verde Islands, 110–180 met. (*Calvet*), and St. Vincent Harbour, Cape Verde Islands, 10 fath., collected by Crossland.

SCRUPOCELLARIA MACANDREI, *Busk.* (Plate 1. figs. 3–7, 11.)

For synonyms see Waters, "Bry. from Zanzibar," Proc. Zool. Soc. 1913, p. 477, pl. 58. figs. 5, 6.

This has a separable operculum (fig. 3), which seems to be general in *Caberea*, but not in *Scrupocellaria*. The oral parts are thrown back as in *C. Darwinii*, Busk, and the scutum comes up to the oral aperture, much as in that species. The vibracular chambers are larger than is usual in *Scrupocellaria* and spread diagonally halfway across the dorsal surface, but they are not as large as is usual in *Caberea*. The seta of the vibraculum is smooth as is general in *Scrupocellaria* *. It will be seen that this species has some characters of *Caberea*, showing how closely that genus is allied to *Scrupocellaria*. The seta is serrate, or, more strictly, spinous at one side only, in *C. grandis*, Hincks, *C. lata*, Busk, *C. rostrata*, Busk, *C. Ellisii*, Flem., *C. Boryii*, Aud., *C. Hookeri*, Busk, *C. glabra*, MacG., *C. bursifera*, Ort., *C. Darwinii*, Busk, *C. minima*, Busk. The vibracular seta has several irregular projections at the base, and at each side there is a separated curved chitinous piece, against which the vibraculum evidently works. The central vibracular muscles draw down the seta, and the sac-like "peculiar body" naturally varies in position with the movements of the seta; but, besides the large † muscles, there is another muscle placed further away from the beak (fig. 4, *m.*), attached to the flexible wall proximal to the seta, and thus the chamber-wall is drawn in, reminding us of the way in which the front membranous wall is drawn down in *Micropora*, *Steganoporella*, *Cupularia*, and other genera. The lateral muscles are attached to projections on the base of the vibracular seta (fig. 5).

There is a small median avicularium placed near to the base of the scutum. Miss Thornely refers to tall median avicularia. There is a chitinous arch from the inner side of the area below the scutum. The ovicell is imperforate, and there are 13 tentacles.

Loc. Coast of Spain; Adriatic; Lifu (*Thornely*); Queensland (*Haswell*); Zanzibar, 8 fath. (*Waters*); in the Indian Ocean (Providence, 50–78 fath., Amirante, 29 fath., Farquhar reef, Cargados, 30 fath., Seychelles, 34 fath.)

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* In my paper on the Zanzibar Cheilostomata, Proc. Zool. Soc. 1913, p. 474, I unfortunately stated that the vibracula of *Caberea* were smooth, which presumably was a slip in transcribing.

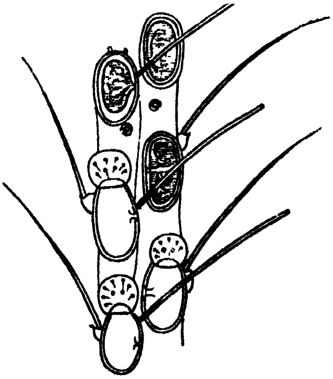
† With the circular movement of the seta it is questionable whether any of the muscles should be called retractor or occlusor

(*Th.*); St. Paul's Rock, N. Atlantic (*Chall.*); St. Vincent, Cape Verde Islands, 1070–1150 fath. (*Chall.*), Cape Verde Islands, 110–180 met. (*Calv.*); Boa Vista, Cape Verde Islands, collected by Crossland.

SCRUPOCELLARIA TRIDENTATA, sp. nov. (Plate **1.** figs. 9, 10.)

Zoarium spreading in all directions, forming a circular growth, in most respects agreeing with *S. cervicornis*, Busk, but below each bifurcation there is a very large raised avicularium, of which the mandible has three long narrow prongs, and the avicularian chamber folds inwards round three projections to receive these prongs as in a half-open tube (Pl **1.** fig. 10). In other parts there is an anterior avicularium on each zoœcium, just below the area *. Hincks describes avicularia below the area on a tall columnar process, in *S. cervicornis*, Busk.

Fig. 1.



Scrupocellaria tridentata, sp. nov. × 50.

There are about six oral spines, none of which are bifurcate; down the middle of the zoarium there are very long stout erect spines, and these in one internode will all belong to the zoœcia on the right side, whereas in the companion internode of the same age they will belong to the zoœcia on the left side, in both cases growing from near the distal end. Hincks refers to tall spines on each side of the branch in *S. cervicornis*, and when a colony of *S. tridentata* is seen from the side the spine appears to grow from the side.

The lateral avicularia are very minute, being smaller than those figured by Smitt † in his *S. cervicornis*. Smitt calls attention to the variation in the size of the lateral avicularia in *S. cervicornis*, and also makes comparisons of *S. pusilla*, Smitt, *S. cornigera*, Smitt, and *S. cervicornis*, Busk. MacGillivray figures the Australian form with large avicularian mandibles. This species, *S. cervicornis*, Busk, *S. cornigera*, Smitt, and *S. obtecta*, Hasw., have very similar scuta. There are about seven zooecia in an internode. There is no separable operculum, the ovicell is perforate, the radicles are serrate, and the smooth vibracular setæ are about three times the length of a zooecium.

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* Hincks, Ann. Mag. Nat. Hist. ser. 5, vol. xi. (1883) p. 103.

† "Floridan Bryozoa," Pt. I. p. 15 (1872).

Loc. Boa Vista, Cape Verde Islands, 20 fath., collected by Crossland.

BEANIA HIRTISSIMA, *Heller*. (Plate 1. fig. 2.)

Diachoris hirtissima, Heller, "Die Bryozoen des Adriat. Meeres," Verhand. der k.k. zool.-bot. Gesellsch. Wien, vol. xvii. (1867) p. 94, pl. 1. figs. 6, 7; Busk, Rep. of the Voyage of H.M.S. 'Challenger,' vol. x. Polyzoa, p. 61 (1884).

Chaunosia hirtissima, Busk, Q. Journ. Micr. Sc. n. s. vol. vii. (1867) p. 241, pl. 36. figs. 12–14.

Beania hirtissima, Waters, "On the Use of the Avicularian Mandibles in determination of the Cheil. Bry.," Trans. Micr. Soc. ser. 2, vol. v. (1885) pl. 14. fig. 5; "Bry. from Rapallo, &c.," Journ. Linn. Soc., Zool. vol. xxvi. (1896) p. 17; "Bry. from Madeira," Journ. R. Micr. Soc. 1899, p. 15; Calvet, "Bry. Mar. de la Rég. de Cette," Trav. Inst. de Zool. de l'Univ. de Montpellier, ser. 2, Mém. 11, p. 24 (1902); Expéd. Sc. du 'Travailleur' et du 'Talisman,' Bryozoaires, vol. viii. (1907) p. 392; Norman, "Polyzoa of Madeira," Journ. Linn. Soc., Zool. vol. xxx. (1909) p. 286.

In the specimens from the Cape Verde Islands there are no radicle-tubes, and none seem to occur in the typical form of this species from other localities, so far as examination has gone, but there are, in these Cape Verde specimens, delicate spines which sometimes are entire, but more often they bifurcate near the base, and usually there are two such spines on the dorsal surface of each zooecium. Busk, in describing his *Chaunosia* the same year as Heller with the same specific name, refers to the bi-trifurcate dorsal spines. The zoarium of Busk's *Chaunosia* is like the form of *cylindrica* of Hincks. In looking carefully through some specimens from Naples and Rapallo a few such spines, similarly bifurcating, were found, but only in isolated cases, whereas they are very numerous in the Cape Verde specimens, which in most respects correspond fairly closely with the Mediterranean specimens. On the anterior border there are about nine delicate spines on each side, while further away from the border, with no great regularity, there are a number of much stouter spines. Round the distal part of the aperture there are usually seven fairly stout spines with other spines nearer to the dorsal surface.

The variety *robusta*, Hincks, which I think might well be separated as a species, has long thin dorsal tubes or radicles; *B. conferta*, MacG., has numerous long dorsal spines; *B. spinigera*, MacG., has no dorsal spine or tube; *B. elongata*, Hincks, has a small dorsal tube near the distal end; *B. magellanica*, Busk, has a wide radicle-tube near the distal end, thus showing the value of the dorsal surface in determination.

Loc. Adriatic, Naples, Capri, Rapallo, Villefranche-sur-Mer (*Waters*), Ajaccio, (*Calvet*); Madeira (*Waters & Norman*); New Zealand (var. *robusta*); St. Vincent, Cape Verde Islands (*Chall.*); St. Vincent Harbour, Cape Verde Islands, 10 fath., collected by Crossland.

MEMBRANIPORA TENUIROSTRIS, *Hincks.*

Membranipora tenuirostris, Hincks, Ann. Mag. Nat. Hist. ser. 5, vol. vi. (1880) p. 70, pl. 9. fig. 3; *op. cit.* ser 5, vol. x. (1882) p. 7; *op. cit.* ser. 5, vol. xix. (1887) p. 314; Waters, Journ. R. Micr. Soc. ser. 2, vol. v. (1885) p. 775, pl. 14, fig. 41; Quart. Journ. Geol. Soc. vol. xlvii. (1891) p. 11; Journ. Linn. Soc., Zool. vol. xxi. (1898) pp. 668 & 685, pl. 47. fig. 7.

Membranipora Flemingii, Waters, Ann. Mag. Nat. Hist. ser. 5, vol. iii. (1879) p. 122, pl. 13, fig. 2.

In the specimens from the Cape Verde Islands some parts have the spines as figured by Hincks, whereas in others there are none. In my paper on Membraniporidæ I referred to the spines not occurring in Naples and Rapallo specimens.

Loc. Queen Charlotte Islands (*Hincks*); Madeira on *Pinna* (*Hincks*); Naples, low water to 40 fath.; Capri; Rapallo; Adriatic; Oran (Algiers), 54 fath.; St. Vincent Harbour, Cape Verde Islands, 10 fath., collected by Crossland.

Fossil. Bartonian and Pliocene of Italy.

MEMBRANIPORA CURVIROSTRIS, *Hincks.*

Membranipora curvirostris, Hincks, Ann. Mag. Nat. Hist. ser. 3, vol. ix. (1861) p. 295 (39), pl. 7. fig. 4; Brit. Mar. Polyzoa, p. 153, pl. 20. figs. 5, 6 (1880); Ridley, Proc. Zool. Soc. 1881, p. 46; Waters, Journ. Linn. Soc., Zool. vol. xxvi. (1898) pp. 668 & 684, pl. 47. figs. 2, 12.

Some of the zoœcia have a median spine below the area, also one or two spines in various other positions. There is the unoccupied space above the avicularium as in the British and Naples specimens.

Loc. British, Polperro, 40 fath; Singapore? ; Brazil, 35 fath. (*Ridley*); Naples; St. Vincent Harbour, Cape Verde Islands, 10 fath., on clinker and from a diver, collected by Crossland. * [Dwarka, Arabian Sea (*Thornely*).]

MEMBRANIPORA QUADRICORNUTA, sp. nov. (Plate 1. fig. 8.)

There are incrusting specimens from St. Vincent Harbour, Cape Verde Islands, 10 fathoms. The opesia is oval, and at the distal end on each side there is a short cervicorn spine, and lower down there is another pair. There are a considerable number of vicarious avicularia just like those of *M. crassimarginata*, Hincks †—in fact, the species is like *M. crassimarginata*, except that there are two pairs of cervicorn spines. The avicularia are about as long as the ordinary zoœcia, but not quite so wide. The border is crenulated.

There is one distal rosette-plate about the middle of the distal wall, and two lateral rosette-plates about halfway between the anterior and basal wall.

There is considerable irregularity in the spines, for the lateral ones at first have only two points, whereas later there may be several divisions, and those

[* Thornely, Hyd. & Poly. coll. at Okhamandal in Kattiawar. 1916.]

† Ann. Mag. Nat. Hist. ser. 5, vol. vi. (1880) p. 71, pl. 9. fig. 1.

from opposite sides may interdigitate, or in a few cases may be fused together, thus forming a good protection. In some cases there is a second spine on each side near the proximal end, but this is not common; also in one zoœcium I have found a central proximal spine. The oral spines stand erect, and therefore it is impossible to give an idea of them as seen from above—consequently a few pressed down are drawn to show the shape.

CRIBRILINA RADIATA (*Moll*), *Smitt.*

The specimens from the Cape Verde Islands are fairly typical *C. radiata*, a species subject to much variation. They have about 11 ribs, and there are 5–7 pores in a ray. There is no suboral pore visible, but in dried specimens, afterwards decalcified, a row of 6 pore * disks is seen below the aperture with a single pore in the middle, the same size as the others, but this semicircle of pores must probably be considered as the upper series of the radial pores. On each side of the central pore there is usually a small nodule. By the side of the more or less oval zoœcia there are elongate avicularia, as frequently described; as is generally the case in *Cribrilina*, there is no avicularian cross-bar, though one occurs in *C. monoceros*, Busk, which, however, most workers would now remove from *Cribrilina* on other grounds. The large bordering spines to which reference will be made are about 11, the two upper ones, being much longer than the others, have been mistaken for setæ or vibracula.

In a stained specimen, from Rapallo, the small frontal pores are each in the centre of a much larger disk.

The ovicells have nodules, and sometimes a keel dividing to each lower corner.

The opercula are separable and are of quite the same type as in *C. punctata*, Hass., *C. Gattyæ*, Hincks, *C. Balzaci*, Waters, and I fail to see any reason for separating a genus *Puellina*, Jullien, as maintained by Levinsen.

The primary zoœcium has 11 spines, while that of *C. punctata*, Hass., has 12 (Harmer), that of *C. projecta*, Waters, has 12, that of *C. monoceros*, Busk, has 9 (Harmer), that of *C. Gattyæ*, Hincks, has 11, while the closely allied *C. Balzaci*, Waters, has a primary zoœcium similar to the ordinary zoœcia, and this, according to Harmer, is also the case in *C. annulata*, Fabr. The primary of *Membraniporella nitida*, Smitt, has 10 spines fairly regularly surrounding the zoœcium, but it may be seen that 6 are oral spines and 4 zoœcial. Hincks evidently made a mistake in describing 14 spines, for his figure in Brit. Mar. Poly. pl. 27. fig. 6 is clearly not a primary. In *M. nitida* a number of zoœcia, after the primary, have a Membraniporidan character somewhat like *M. lineata*, Hincks, and taking a fairly typical colony of *M. nitida* from Oban, Scotland, the second series have

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* In speaking of pores it is not meant that there is a direct opening to the interior.

6 oral spines and two or three delicate zoœcial ones. The following series have 4 distal spines and 2 oral. None of the subsequent zoœcia have lateral spines, while in the next series (circle) there are two zoœcia with two distal spines and one oral on each side; whereas two other zoœcia in the same series have the flat spines characteristic of *nitida* and meeting in the median line. Thus the early zoœcia are distinctly Membraniporidan, in each row approximating gradually to the mature *nitida*.

There are several cases in the Cellularidæ, and other families, in which the zoœcia immediately following the primary are intermediate between it and the following zoœcia.

Hincks, Norman, and Levinsen have placed *Membraniporella* under Cribrilinidæ, and Norman * has written a lengthy description of the bars or spines, comparing them with other Cribrilinidæ, but what he describes as the loop is only the base of the spine arising from the lateral wall. His figures (pl. 8. figs. 8, 9) are difficult to understand without examination of specimens and are far from satisfactory. The bars are simply spines such as we see in many *Membraniporæ*, and they do not touch their neighbours at the side continuously for the whole length. These spines are an arch over the frontal membranous wall with which they are not in contact, and the operculum, which is of a Membraniporidan type, is not separable, and is in the membrane in no way connected with the spines. We may ask if there is any reason for generically separating it from *Membranipora*, and must answer, No—as Smitt has already done.

The ridges of *Cribrilina* have been supposed to show that it was very closely allied to *Membraniporella nitida*, but the difference is much greater than first appearances suggest.

In 1879 † I mentioned minute spines round the area of *C. Gattyæ*, Hincks, and since then Harmer ‡ has described spines surrounding *C. radiata* §. I have made decalcified and stained preparations, and even decalcified preparations of dried specimens of various species, for they often show important structures, and these preparations led me to doubt the theory of the frontal wall being formed of confluent spines. My decalcified preparations of *C. radiata* from several places show a row of bluntly pointed, erect spines round the border of the zoœcium, with the two distal ones much longer and narrower than the others, and acute. Of course, these free erect spines have nothing to do with the ribs (ridges). I am thus able to confirm part of what Harmer has written on this point, though it may be somewhat differently stated, and the rows of small radial pores are, as mentioned by Harmer, in line with these spines, and in between are the ribs. We have been accustomed to speak as if the ribs were the most important frontal structure, whereas it seems that it is the pores which are the more important, with the ribs produced later and of secondary importance. In specimens of *C. Balzaci*, and in other species the young zooecia, with only a membranous front, show the pore disks before any calcification takes place, and we may see in many forms that calcification has formed round these pore disks; and Norman in his figures of *C. nitido-punctata*, Smitt, and *C. Gattyæ*, Hincks, shows a thicker calcareous deposit round the disks, though he did not appreciate the importance of his observation. Where there is a distinct area, as in *C. Balzaci*, &c., and in *C. figularis*, Hincks, there is a surrounding row of large pore disks, often dark and chitinous, with smaller transparent pores, radiating from the centre, from these large disks. These large pores are probably vestigial, seeming to give a record of ancestors having had spines. The frontal wall of *C. radiata* occurs right up to the spinous circle, and may be attached to the spines, but this does not justify our assuming that the frontal wall of either *C. radiata* or other *Cribrilinæ* is formed by overarching spines, and it is the supposed resemblance to *Membraniporella nitida* which has led to this assumption. There are a great many species in various genera in which there is a more or less radial arrangement of the pores, and a fuller study of *Cribrilina* should explain various structures, for of course the spines and pores show a close developmental connection, even though former explanations may not be correct.

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* "Natural History of East Finmark," Ann. Mag. Nat. Hist. ser. 7, vol. xii. (1903) pl. 8. fig. 18, pl. 9. figs. 4, 6.

† "Bry. of the Bay of Naples," Ann. Mag. Nat. Hist. ser. 5, vol. iii. (1879) p. 36, pl. 9. fig. 6 *a*.

‡ "On the Morphology of the Cheilostomata," Q. Journ. Micr. Sci. vol. xlvi. p. 326.

§ Probably these must be compared with the large stout spines which I figured round *Hippothoa Brongniartii*, d'Orb. in Ann. Mag. Nat. Hist. ser. 7, vol. xv. (1905) p. 10, pl. 1. figs. 2-4; and also with the spines of *Lepralia Poissonii*, Hincks.

The opercula measured range in size from *C. radiata* (form called *setosa*, Waters) 0·07–0·08 mm.; *C. radiata*, Cape Verde Islands, 0·08 mm.; *C. Gattyæ*, 0·07 mm.; *C. radiata*, some specimens, 0·1 mm.; *C. Balzaci*, 0·1 mm.; *C. punctata*, Hass., 0·12 mm.; *C. patagonica*, Waters, 0·15 mm.; *C. figularis*, Hincks, 0·17 mm.; *C. latimarginata*, Busk, 0·2 mm.; *C. monoceros*, Busk, and *C. acanthoceros*, MacG., 0·22 mm.

C. patagonica, Waters, has on the under surface of the operculum projections of a *Membranipora* type.

Norman* still considers that there are two species, *C. radiata* and *C. innominata*, although most workers have united them, but in my own collection I am unable to find characters by which they can be separated. In British, Naples, and Madeira specimens, which Norman would probably call *innominata*, there are frequently many avicularia, though some specimens may have few or none. The number of ribs varies from 8–20; the elevation of the so-called bars is not a satisfactory distinction.

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* "Polyzoa of Madeira," &c., Journ. Linn. Soc., Zool. vol. xxx. (1909) p. 291.

It is advisable to call attention to the similarity between the primary zooecia described by Smitt in his *Discopora coccinea*[*], *D. ventricosa*[†], Smitt, *D. stenostoma*[‡], Smitt, and the mature zoœcia in certain *Cribrilinæ* such as *C. Gattyæ*, *C. Balzaci*, and to a certain extent *C. figularis*, Hincks.

Loc. Very widely distributed. St. Vincent Harbour, 10 fath., collected by Crossland.

Fossil. Eocene, Miocene, and Pliocene.

THALAMOPORELLA ROZIERI (*Audouin*), *Hincks*. (Plate 4. figs. 9, *a*, *b*, *c*.)

For synonyms and localities see Waters, "Bryozoa of the Sudanese Red Sea," Journ. Linn. Soc., Zool. vol. xxxi. (1909) p. 141, pl. 15. figs. 12–15, and add :—? Robertson, "Incrust. Chil. Bry.," Univ. of California, Pub. Zool. vol. iv. (1908) p. 277, pl. 17. figs. 27, 27 *a*, 28, 29, pl. 18. fig. 30; Levinsen, Morph. & Syst. Studies on the Cheil. Bry. p. 181, pl. 6. figs. 6 *a*–6 *k*, pl. 6 *b*. figs. 1 *a*–3 *b* (1909) ; ? Osburn, "Bry. of the Tortugas Islands, Florida," Publ. 182, Carnegie Inst. of Washington, p. 196 (1914).

Vincularia novæ-hollandiæ, Haswell, Proc. Linn. Soc. N.S. Wales, vol. v. (1881) p. 41, pl. 3. fig. 3.

Thalamoporella novæ-hollandiæ, Levinsen, Morph. & Syst. Studies on the Cheil. Bry. p. 185, pl. 6 *a*. figs. 3 *a*–3 *f* (1909).

The form from the Cape Verde Islands is the same as that from the Red Sea, described by me in the "Sudanese Red Sea" Report, which must be taken to represent the type well figured by Savigny, who apparently found no avicularia, and the opercular knobs were very pronounced ; but in the Cape Verde Islands specimens there is great variation in this respect, and sometimes in the younger parts of a colony none are seen, whereas in older parts they occur as figured by Savigny. This is a very variable character throughout the family. Of the varieties figured by Hincks[§] the one most nearly approaching the Red Sea form is *Steganoporella Rozieri*, var. *indica*, Hincks, whereas the variety *falcifera* seems entitled to specific rank as proposed by Levinsen. Probably var. *labiata*, Levinsen, should also be given generic position as the type of avicularia is different.

Most of the zoœcia are about 0·65 mm. long, but some are longer, others shorter, and this is about the size of co-type specimens of *T. novæ-hollandiæ*, Hasw., sent to me by Haswell. These I have considered were *T. Rozieri*, but as my specimens were without membranes they were not suitable for studying the spicules; however, examination shows a "curve" (spicule), which Levinsen says does not occur. It is somewhat larger than the average size in *T. Rozieri* from the Red Sea and Cape Verde Islands. My specimens of *novæ-hollandiæ* are cylindrical and hollow, while Levinson speaks of the colonies being partly incrusting, partly free hollow branches, and I see no sufficient ground for separating *T. novæ-hollandiæ* from *Rozieri*. Further cleaning of one of my specimens, sent by Haswell, revealed an avicularium similar to the one figured by Levinsen. With ovicells and avicularia unknown, it was difficult to be certain of the specific identity.

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[*] "Krit. Förteck. öfv. Skand. Hafs-Bry.," Öfv. Kongl. Vet.-Akad. Förh. (1867), Bih. pl. 27. fig. 163.

[†] Ib. (1871) pl. 21. fig. 31.

[‡] Ib. (1871) pl. 21. fig. 29.

[§] Ann. Mag. Nat. Hist. ser. 5, vol. vi. (1880) p. 379, pl. 16. fig. 1.

Levinsen's studies of the spicules in *Thalamoporella* are most important, but we do not know much as to the positions in which they occur, nor as to their object. In *T. Rozieri* from both the Red Sea and Cape Verde Islands there are two bundles of the long straight spicules starting from near the opercula and passing diagonally by the walls of the opesiules to the lateral walls, near the basal wall (Pl. 4. fig. 9). The long straight spicules are mostly free in the zoœcium, and at one time I wondered whether they were arranged in this way by the polypide passing in and out of the zoœcium, but these bundles occur in very young zoœcia before any calcareous frontal wall or operculum is formed. There are on, or in, the membranes spicules which Levinsen called curves, but in the sponges they would be called sigmas or arcuate spicules, and perhaps it would be well to speak of them as sigmas. These are remarkably abundant in *Th. Jervoisi*, H., and *T. mamillaris*, Lamx., from various localities. A specimen of *Jervoisi*, from Queensland, in my collection, has these spicules in great abundance in both the basal and frontal membranes, and at the growing end where the beginning of the lateral wall is only just indicated, on the supporting seaweed, these sigmas are massed in abundance.

Dr. Alice Robertson considers that her specimens, from La Jolla, California, are var. *indica*, Hincks, which hardly seems to differ from the type, others from San Pedro are articulated, and I expect this will ultimately be generically separated. Osburn considered his specimens from Tortugas Island were var. *labiata*, Levinsen, but the difference of the avicularium as figured by Levinsen may suffice to make *labiata* a genus. I do not consider that the presence or absence of avicularia is of first class importance, as often some colonies of *Thalamoporella* may have them while others are without; on the contrary, the type of avicularium and mandible is of material importance.

Localities, additional. California, few fath.: San Diego (*Robertson*), Florida, Jamaica, Tortugas Bay; Cape Verde Islands, St. Vincent Harbour, 10 fath., collected by Crossland.

SCHIZOPORELLA UNICORNIS (*Johnston*), *Pergens*. (Plate 2. figs. 14–17, 22.)

For synonyms see Waters, "Bryozoa of the Sudanese Red Sea," Journ. Linn. Soc., Zool. vol. xxxi. (1909) p. 143, pl. 12. figs. 12, 13, and add:—

Nordgaard, Die Bry. des West Norweg. p. 86 (1903); Hydrog. & Biol. Invert. in Norwegian Fiords, p. 165, pl. 5. figs. 23–25, 27 (1905); Calvet, Expéd. Sc. du 'Travailleur' et du 'Talisman,' vol. viii. (1907) p. 417; Norman, "Polyzoa of Madeira and neighbouring Islands," Journ. Linn. Soc., Zool. vol. xxx. (1909) p. 303; Osburn, "*Bry. of Woods Hole Region*," Bull. Bur. of Fisheries, vol. xxx. (1912) p. 236, pl. 25. fig. 48, pl. 30. fig. 91; "Bry. of the Tortugas Islands, Florida," Publ. 182, Carnegie Inst. of Washington, p. 205 (1914); Waters, "Bry. from Zanzibar," Proc. Zool. Soc. 1914, p. 831.

Crossland sent some thick pieces from underneath a coal-lighter, in St. Vincent Harbour, Cape Verde Islands, and says. "this is the first of the host of forms to make an attachment to the lighter." One block was about 170 mm. × 140 mm and 7 mm. thick. Some colonies occur on a stone brought up by a diver. In my last two papers [*] it has been pointed out that the zooecia are frequently superimposed, and this I referred to in a species of *Meliceritites.* Reuss has shown the same thing in *Cumulipora angulata,* v. Maehr, and Lee [†] calls attention to Ulrich [‡], saying, "in the Trepostomata and many Cryptostomata the tubular zooecium really represents a series of superimposed cells."

This species shows the "closures" more clearly and distinctly than any other I have come across. The calcareous matter is evidently deposited by a cellular tissue over the operculum. When a zoarium consisting of several layers is examined from below, the chitinous opercula in the older layers may nearly all be seen remaining in the oral aperture in their natural position, and when the zooecia from these lower layers are examined from above the opercula are mostly without any calcareous growth, while others have a calcareous layer over part or all of the operculum. Near the centre of the operculum, or rather distal to the centre, a tubule grows through this super-opercular deposit, which may be quite short (figs. 14, *a, b*) or may form a noticeable tube, for in one case a fine tubule joins the inner wall of the next layer of zooecia (fig. 14, *d*). The mandibles in *S. spongites,* Smitt, are also sometimes similarly covered with a calcareous deposit.

Schizoporella viridis, Thornely, in large masses, shows in the upper layers no calcareous deposit on the opercula, nor any tubule or tubercle ; but when the upper layer is scraped away, then the opercula of the underlying zooecia are mostly seen to have a stout tubercle over the middle, but only in a few cases is there any calcareous deposit. The new zooecia in *S. viridis* are placed irregularly, quite independently of the layer below, and only accidentally do the walls of the new zooecia pass over the old opercula, but where this has occurred there is in one or two cases a thickening of the operculum under the new wall. We thus see that the position of the layers of zooecia is quite different in *S. viridis* (fig. 18) to what occurs either in *S. unicornis* or in *S. porelliformis* [§], nov. (Pl. 2. figs. 19–21, an African species which I have long known in manuscript), there being important specific differences in each.

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[*] "Bry. Sudanese Red Sea," Journ. Linn. Soc., Zool. xxxi. (1909) p 144; "Bry. from Zanzibar," Proc. Zool. Soc. 1913, p. 502.

[†] "Brit. Carb. Trepostomata," Mem. Geol. Surv. of Great Brit, Paleont. vol. i. pt. 3, p. 145 (1912).

[‡] Ulrich, E. O., "Pal. Bry.," Pal. of Illinois, Geol. Survey Illinois, vol. viii. pt. 2, p. 322 (1890).

[§] *Schizoporella porelliformis,* sp. nov. (Pl. 2. figs. 19–21). It is much like *S. nivea* in most characters, but is larger with larger aperture, &c. The surface and the large round ovicells have large pitted pores. It is bi-multilaminate. The oral aperture is nearly round, as the sinus is nearly the width of the aperture. The operculum has the muscular attachments at the side, and not from bosses distant from the border. There are one or two small oval avicularia at each side of the aperture.

The closures and tubules are very important, as the same thing occurs in various recent and fossil Cheilostomata [*], though often called "opercula," as it has frequently been supposed that the aperture was closed by this calcareous film, independently of the chitinous operculum, whereas from analogy we may feel sure that the calcareous deposit was formed over the operculum, there being therefore an important structural difference in the closures of the Cheilostomata and Cyclostomata, so that, in fact, it is doubtful whether the name closure should be used for the deposit in the Cheilostomata.

In *Meliceritites* (fossils very abundant in the Jurassic and Cretaceous formations) the closures with tubules are very common, and I have shown that the family had avicularia with mandibles; it also had opercula, and we now know that such closures and tubules are not restricted to the Cyclostomata. The new layer in some species of *Meliceritites* has the distal wall passing over the operculum of the under layer just as described in *Schizoporella nivea* [†], Busk. Further, the shape of the zooecia in *Meliceritites* is not regularly tubular as in Cyclostomata. As we have several truly Cheilostomatous characters I have protested against *Meliceritites* being called Cyclostomata; on the other hand, Gregory and Levinsen have shown that the large ovicells have Cyclostomatous characters, which may be sufficient to prevent the family being placed with Cheilostomata; certainly it should never be called Cyclostomata.

Levinsen [‡] speaks of layers of growth being a Cyclostomatous character, but there are several *Schizoporellæ* with multi-layered growth, and this is often the case in *Adeonella*, *Cellepora*, *Micropora*, &c.

In examining the opercula of *S. unicornis* in decalcified material I came across a very abnormal double one, having two proximal ends, each with a wide arc, like those of the normal form, and there are four muscular dots (fig. 22).

Loc. Generally distributed in the northern hemisphere and the tropics. St. Vincent Harbour, Cape Verde Islands, 10 fath., collected by Crossland.

SCHIZOPORELLA SPONGITES (*Pallas*), *Smitt*. (Plate 2. figs. 10–13.)

Eschara spongites, Pallas (*pars*), Elenchus Zoophytorum, p. 47 (1766).

Hippothoa spongites, Smitt, Floridan Bryozoa, p. 42, pl. 8. figs. 161–168 (1873).

Schizoporella spongites, Thornely, Report on Pearl Oyster Fisheries of the Gulf of Manaar, p. 114 (1905); Levinsen, Morph. & Syst. Studies on the Cheil. Bryozoa, p. 324, pl. 18. figs. 4 *a–d* (1909); Osburn, "The Bryozoa of the Tortugas Islands, Florida," Publ. 182, Carnegie Inst., p. 207 (1914).

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[*] "Bry. from Zanzibar," Proc. Zool. Soc. 1913, p. 504.

[†] "Bry. from Zanzibar," Proc. Zool. Soc. 1913, pp. 503, 504.

[‡] "Studies of the Cyclostomata Operculata," K. Danske Vid. Skr. vol. x. (1912) p. 19.

From the Cape Verde Islands there are two specimens, one of which is 11 cm. × 7 cm. They are solid, many-layered masses (up to 25 layers), rising in places into large mammillated mounds. These specimens are white and have been dead some time, as there are no opercula. Besides these there are a few colonies growing on stone forming one or two layers. Lower than the oral aperture, on one or both sides, there is a small avicularium with acute mandibles, and there is sometimes a small central umbo. The frontal surface is perforated, except just below the aperture, and there are large vicarious avicularia scattered about. Above the oral aperture there is a lined or crenulated ridge. The oral aperture has two denticles by the proximal edge, as can be seen from above (fig. 11), or better from the interior (fig. 12), and the operculum shows two hollows into which these denticles fit; these are what Busk calls "foramina" in *Cellaria*, and I have shown * that they are sockets into which the teeth fit. The operculum is drawn from a specimen from Manaar, kindly given to me by Miss Thornely, and with regard to the minute details of the aperture and the surrounding ridge, &c., it corresponds in every detail with the specimens from Cape Verde, but does not have more than two layers of zoœcia in any part.

The ovicell is very large, being about twice the size of that of *Schizoporella unicornis*, Johnst., with a pitted surface, and at the opening two denticles directed distally, but I have not seen them nearly meeting, as figured by Levinsen. The ovicell usually quite conceals the oral aperture, and it is quite exceptional for any trace of the aperture to be seen, as already mentioned by Levinsen.

The large vicarious avicularia occur frequently in a large number of species called *Cellepora*, and certainly most of the older writers would have placed this, with its solid irregular growth, under *Cellepora*; however, it has long been recognized that many species known as *Cellepora* must be united to *Schizoporella*.

I have said † that the *Cellepora spongites*, Pall., was *Schizoporella unicornis*, the form which I called *errata*, and this I consider to be the case, but apparently, from the reference to previous figures, and from his description, Pallas was considering three distinct species, namely *Schizoporella unicornis*, and *S. sanguinea*, Norm., both from the Mediterranean, while the one he last refers to from America is what Smitt placed as *S. spongites*, though where only zoarial characters are referred to it is impossible to speak with absolute certainty, as two species may correspond zoarially. The first two species are now well known under other names and "*spongites*" has been used by several authorities, so that even if rules should suggest a new name it would seem as if the plan adopted by Levinsen is the best—that is, to call it *S. spongites* (Pallas), Smitt.

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* Report of the Voyage of the 'Challenger,' vol. xxxi. pt. 79, p. 16.

† Journ. Linn. Soc., Zool. vol. xxxi. (1907) p. 145.

Oran (Algiers); Florida; Vineyard Sound, Buzzard Bay, 1–19 fath., No Man's Land, Nantucket, Sandwich (*Osburn*); from underneath a coal-lighter *in St. Vincent Harbour, Cape Verde Islands, collected by Crossland.*

HIPPOTHOA DISTANS (*Hincks*).

Cosmopolitan.

HIPPOTHOA DIVARICATA, *Lamouroux*.

For synonyms see Miss Jelly's Catalogue, and add:—

Waters, Résult. du Voyage du S.Y. 'Belgica,' Bryozoa, p. 53, pl. 7. fig. 3 (1904); "Bry. from near Cape Horn," Journ. Linn. Soc., Zool. vol. xxix. (1904) p. 238; "Bry. from Zanzibar," Proc. Zool. Soc. 1913, p. 501; Nordgaard, Hyd. & Biol. Invest. in Norwegian Fiords, p. 165 (1905); Robertson, "Incrust. Chil. Bry. of N.W. Coast of America," Univ. of California, Pub. Zool. vol. iv. (1908) p. 296, pl. 21. figs. 59, 60; Norman, "Polyzoa of Madeira," Journ. Linn. Soc., Zool. vol. xxx. (1909) p. 299.

Loc. Cosmopolitan, including Woods Hole, Madeira, and between Fayal and Pico. From slight depths to 1000 fathoms.

HIPPOTHOA HYALINA (*Linnæus*), *Waters.*

For synonyms see *Schizoporella hyalina* in Miss Jelly's Catalogue, and add:—

Mollia hyalina, Barrois, Emb. des Bry. p. 163, pl. 9. figs. 4–17 (1877).

Schizoporella hyalina, Levinsen, Zool. Dan. 'Danske Dyr' (1894), p. 66, pl. 5. figs. 47–57; Robertson, "Bryozoa," Proc. Washington Acad. of Sc. vol. ii. (1900) p. 326; Calvet, Bry. Mar. de Cette, p. 44 (1902); Hamburg. Magalh. Sam, Bry. p. 25 (1904); Expéd. Sc. 'Travailleur' et 'Talisman,' vol. viii. (1907) p. 415; Robertson, Incr. Chil. Bry. p. 289, pl. 19. figs. 43–45 (1908).

Hippothoa hyalina, Waters, "Bry. from Franz Josef Land," Journ. Linn. Soc., Zool. vol. xxviii. (1900) p. 70, pl. 8. figs. 16–18; "Bry. from Chatham Island," Ann. Mag. Nat. Hist. ser. 7, vol. xvii. (1906) p. 19; Norman, "Nat. Hist. Finmark," Ann. Mag. Nat. Hist. ser. 7, vol. xii. (1903) p. 108; Nordgaard, Hydr. & Biol. of the Norwegian Fiords, p. 165 (1905); Kluge, "Erg. üb. die von der Olga gesamm. Bry.," Biol. Anst. auf Helgoland, vol. viii. (1906) p. 39; Levinsen, Morph. & Syst. Studies on Cheil. Bry. p. 276 (1909); Osburn, Bry. of Woods Hole, p. 235, pl. 24. fig. 47 (1912); Sumner, Osburn & Coles, "Biol. Survey of the Waters of Woods Hole," Bull. Bur. of Fisheries, vol. xxxi. (1913) p. 603.

Celleporella hyalina, Norman, Ann. & Mag. Nat. Hist. ser. 6, vol. xiii. (1894) p. 129; Bidenkap, "Bry. von Ost Spitzbergen," Zool. Jahrb. vol. x. (1897–8) p. 621; "Bry.," Anstalt Helgoland, vol. iv. (1900) p. 252; "Bry. von Spitzbergen und König Karls Land," Fauna Arct. vol. i. (1900) p. 512; "Forteg. ov. de Arkt. Bry.," Bergens Mus. Aarbog, 1905, No. 9, p. 18.

There is one small colony growing on the seaweed with *Amathia.*

Loc. Fairly cosmopolitan from both hemispheres, occurring from tide-levels to over 2000 metres. Cape Verde Islands, collected by Crossland.

ARTHROPOMA CECILII (*Audouin*), *Levinsen.*

Waters, "Bry. from Zanzibar," Proc. Zool. Soc. 1913, p. 508.

Schizoporella Cecilii, Robertson, "The Incrusting Bryozoa of the W. Coast of N. America," Univ. of California Pub. in Zool. vol. iv. (1908) p. 288, pl. 19. fig. 42.

Loc. General in the north temperate zones; Indian Ocean, Australia; Zanzibar shore (*Waters*); Red Sea; Japan; Cape Verde Islands, collected by Crossland.

CHORIZOPORA BRONGNIARTII (*Audouin*), *Hincks.*

For synonyms see Miss Jelly's Catalogue, and Calvet, Expéd. Sc. du 'Travailleur' et du 'Talisman,' vol. viii., Bryozoaires, p. 413, and add:—

Levinsen, Morph. & Syst. Studies on the Cheil Bry., pp. 275, 276 (1909); Angelis D. Joaquin, "Los primeros Briozoos enc. en los Depósitos Plioc. de Cataluña," Mem. de la C. y Artes de Barcelona, p. 36 (1900).

Loc. British and French coasts; Guernsey; Mediterranean; Australia; Dunedin and Foveaux Straits, New Zealand; S. Africa; Canaries; Azores; Madeira; St. Vincent Harbour, Cape Verde Islands, 10 fath., collected by Crossland.

SMITTINA TRISPINOSA, var. PROTECTA, *Thornely.*

Waters, "Bry. from Zanzibar," Proc. Zool. Soc. 1913, p. 513.

Loc. Gulf of Manaar (*Thornely*); Red Sea (*Waters*); Wasin, Brit E. Africa, 10 fath.; St. Vincent Harbour, Cape Verde Islands, 10 fath., collected by Crossland.

SMITTINA TROPICA, *Waters.*

Smittina tropica, Waters, Journ. Linn. Soc., Zool. vol. xxxi. (1913) p. 174, pl. 17. figs. 10–14.

Loc. Red Sea; St. Vincent Harbour, Cape Verde Islands, 10 fath., collected by Crossland.

LEPRALIA ? CUCULLATA, *Busk.*

For synonyms see Waters, "Mar. Biol. of the Sudanese Red Sea, Bryozoa," Journ. Linn. Soc., Zool. vol. xxxi. (1909) p. 150. pl. 15. figs. 1–5, 10, and add:—

Schizoporella cucullata, Jullien et Calvet, Bry. prov. des Camp. de l'Hirondelle, p. 141, pl. 16. figs. 7, 7 *a* (1903); Calvet, Expéd. Sc. du 'Travailleur' et du 'Talisman,' Bryozoaires, vol. viii. (1907) p. 415.

The opercula of specimens from the Cape Verde Islands are somewhat larger than those from the Mediterranean.

Loc. Mediterranean; Red Sea; Mazatlan; Ceylon; California; S. Africa; Azores; Iles Brancot, Cape Verde, 110–180 met. (*Calvet*); St. Vincent Harbour, Cape Verde Islands, 10 fath., collected by Crossland.

LEPRALIA PERISTOMATA, *Waters.*

Lepralia peristomata, Waters, "Bry. from Madeira," Journ. Roy. Micr. Soc. 1899, p. 10, pl. 3. fig. 20; Norman, "Polyzoa of Madeira, &c.," Journ. Linn. Soc., Zool. vol. xxx. (1909) p. 305.

Lepralia Magnevilla, Busk (non Sav. et Aud.), Q. Journ. Micr. Sci. vol. viii. (1860) p. 284, pl. 31. fig. 5.

Two small tubercles can be seen on the front of the operculum towards the proximal part in the position figured by me (*loc. cit.* fig. 20). They can be examined in dried specimens in which the apertures are closed by the opercula.

In *Lepralia peristomata* the peristome entirely surrounds the aperture, whereas in *Lepralia crassimarginata*, Hincks, afterwards described by Jullien as *L. collaris*, there is only an elevation a short distance below the proximal edge of the aperture. There is, however, in *L. peristomata* a great range in the development of the peristome, as some zoœcia show hardly any, whereas in others it is much raised..

Loc. Madeira (*Busk*, *Waters*, *Norman*), 15–70 fath.; St. Vincent Harbour, Cape Verde Islands, 10 fath., collected by Crossland.

SCHIZOTHECA FISSA (*Busk*), *Hincks*.

Lepralia fissa, Busk, Q. Journ. Micr. Sc. vol. iv. (1856) p. 308, pl. 9. figs. 8–10; Waters, Ann. Mag. Nat. Hist. ser. 5, vol. iii. (1879) p. 43, pl. 11. fig. 6.

Schizotheca fissa, Hincks, Brit. Mar. Polyzoa, p. 284, pl. 41. figs. 1–3 (1880); Ann. Mag. Nat. Hist. ser. 5, vol. xix. (1887) p. 303; Neviani, "Bri. post plioc. di Spilinga," Atti d. Accad. Gioen. di Sc. Nat. in Catania, vol. ix. (1896) p. 34, fig. 17; "Bri. delle Form Plioc. e Postpl.," Bull. Soc. Geol. Ital. vol. xvii. (1898) p. 12; "Bri. neog. della Calabria," Pal. Ital. vol. vi. (1900) p. 202, pl. 18. figs. 4, 5; Calvet, "Bry. du Corse," Trav. de l'Inst. de Zool. de l'Univ. de Montpellier, ser. 2, Mém. 12, p. 25 (1902); Exp. Sc. du 'Travailleur' et du 'Talisman,' Bryozoaires, vol. viii. (1907) p. 429; Levinsen, Morph. & Syst. Studies on the Cheil. Bry. p. 294 (1909).

There are only one or two small pieces, and in these a number of the earliest or disk stages of the ovicell occurs, but very few completed ones; in these the "fissure" is not as large as in my British and Mediterranean specimens, but the median portion is thin. Levinsen does not deal, *in extenso*, with the genus, merely putting it in the family Reteporidæ. This has long seemed to be right, as the open ovicell is similar to those of the group of *Reteporæ* with the wide fissure as in *R. Imperati*, Busk *. The labial fissure or pore is also very well marked, and this, as I have said, is an important character of the genus.

Loc. Guernsey; Sidmouth; Plymouth; Cornwall, 30–40 fath.; Ireland; Naples; Capri; Adriatic; Corsica, St. Bonifacio, 55–77 met. (*Calvet and M. Edw.*), Bastia, 40–60 met. (*Calvet*), Bay of Cadiz, 717 met. (*Calvet*); St. Vincent Harbour, Cape Verde Islands, 10 fath., collected by Crossland.

HOLOPORELLA PUSILLA (*Smitt*), *Waters*. (Plate 2. figs. 7–9.)

Discopora albirostris, forma *pusilla*, Smitt, Floridan Bry. p. 70, pl. 12. fig. 233 (1873).

Cellepora sexspinosa, Waters, "Bry. from Madeira," Journ. R. Micr. Soc. 1899, pl. 3. fig. 12; Norman, "Poly. of Madeira," Journ. Linn. Soc., Zool. vol. xxx. (1909) p. 311.

Lepralia Watersi, Calvet, Expéd. Sc. du 'Travailleur' et du 'Talisman,' Bryozoaires, vol. viii. (1907) p. 412, pl. 27. fig. 11.

The younger zoœcia, near the border, show six long spines, whereas the older ones have only one at each side. The ovicell is small, raised, and widely open in front, and at one side of the zoœcia near the aperture there is a small acute avicularium; in a few cases there is one on each side, with occasionally an avicularium in other positions. Generally there is no mucro to the ovicells, though in one specimen many of the ovicells are mucronate, or even might be said to support a long spinous process, and the frontal projection, as figured by Calvet, has been seen. There was no ovicell to the specimen from Madeira. The surface of the zoœcia and of the ovicell is finely granular, and there are a few large pores round tho border of the zoœcia.

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* Waters, "Med. & N. Zeal. Reteporidæ," Journ. Linn. Soc., Zool. vol. xxv. (1894) p. 256.

The aperture measures about 0·08 mm.

Loc. Florida, 9 fath. (*Smitt*); Madeira; Ile Brancot, Cape Verde Is., 20–25 met. (*Calvet*): St. Vincent Harbour, Cape Verde Islands, 10 fath., collected by Crossland.

HOLOPORELLA APERTA (*Hincks*), *Waters.*

For localities see Waters, "Marine Fauna of Brit. E. Africa," Proc. Zool. Soc. 1913, p. 522.

There is only one small colony, growing on a piece of coal, so that no preparation could be made, but there seems no doubt as to the identity.

Loc. Singapore or Philippines; Ceylon; Indian Ocean; Zanzibar and Brit. E. Africa; Cuba; St. Vincent Harbour, Cape Verde Islands, 10 fath., collected by Crossland.

MICROPORELLA CILIATA (*Pallas*), *Harmer.*

For localities see Waters, "Marine Fauna of Brit. E. Africa," Proc. Zool. Soc. 1913, p. 523, and for synonyms add: *Lepralia ciliata*, Barrois, Embryologie des Bryozoaires, p. 149, pl. 7. figs. 4, 6, 7, 15, 19 (1877).

Microporella ciliata, Harmer, "Morph. Cheil.," Q. Journ. Micr. Sc. vol. xlvi. (1902) p. 316; Waters, "Mar. Biol. Sudanese Red Sea," Journ. Linn. Soc., Zool. vol. xxxi. (1915) p. 443; Osburn, "Bry. of Woods Hole Region," Bull. Bur. of Fisheries, vol. xxx. (1912) p. 233; Osburn, Sumner & Cole, "Biol. Survey of the Waters of Woods Hole," Bull. Bur. of Fisheries, vol. xxxi. (1913) p. 601.

Loc. Cosmopolitan; Cape Verde Islands, collected by Crossland.

ADEONELLA CONTORTA (*Michelin*), *Waters.* (Plate 4. figs. 10–15.)

Laminopora contorta, Mich. Magasin de Zoologie, 1842, pl. 8; Waters, "On some Recent Bryozoa in d'Orbigny's Collection," Ann. Mag. Nat. Hist. ser. 7, vol. xv. (1905) p. 10.

Schizoporella contorta, Calvet, Expéd. Sc. du 'Travailleur' et du 'Talisman,' Bryozoaires, vol. viii. (1907) p. 420.

? *Gemellipora arbuscula*, Calvet, *loc. cit.* p. 426, pl. 27. figs. 16–19.

Adeonella contorta, Waters, "A Structure in *Adeonella* (*Laminopora*) *contorta*, Mich. . . . together with Remarks on Adeonidæ," Ann. Mag. Nat. Hist. ser. 8, vol. ix. (1912) p. 489, pls. 10 & 11.

A common character is frequent branching at right angles, often forming but very short branches, as figured (fig. 15) from a colony, collected by Crossland, from St. Vincent, Cape Verde Islands. In some specimens these branches form a semispiral foliaceous growth round the main branch. The specimens under consideration, and those seen in various museums, are generally violet or red, but the colour is not mentioned by Calvet in *Gemellipora arbuscula*, nor are the frequent and short branches, but, as young and even older colonies of *A. contorta* are known without this branching, I consider that it is probably a synonym. It may be well to call attention to the fact that the Adeonidæ are nearly all darkly coloured, but specimens bleached quite white are often seen. There is an interesting specimen of *Adeona* in the British Museum quite white on the one side, though very dark on the other, it evidently having been exposed to the light.

The zoœcia are raised when quite young, but are depressed when older. There is an avicularium on one side, sometimes on both, at about the level of the oral aperture. The oral aperture is elongate with a long sinus and denticles just above the sinus. The zoœcia are small and may be entirely filled up by the embryo, which is about 0·25 mm. long, and, so far as I have seen, there is no external indication as to which are gonœcia.

The older opercula often have a raised tubercle on the front, about the middle, and sometimes there is a calcareous layer over the operculum, forming what has been incorrectly called a calcareous[*] operculum—from this arises the calcareous tubercle. In many of the Cheilostomata a calcareous layer may be formed over the older opercula, and this has been dealt with on page 15. It does not seem right, in any case, to speak of a calcareous operculum.

There are about 13–15 tentacles, and all the Adeonidæ examined have about this number, namely, *A. platalea*, Busk, 13; *A. polystomella*, Reuss, 16; *A. polymorpha*, Busk, 15; *A. lichenoides*, Busk, 14; *Adeonellopsis distoma*, Busk, 14–16; *A. Crosslandi*, Waters, 13–14.

In my paper on *Adeonella contorta*, on page 493, the characters are given of the group dealt with by Busk as *Adeonella*.

Loc. Evidently abundant from the Cape Verde Islands, and, as stated in my paper referred to, it appears to occur in the Red Sea; the John Adams Bank, Brazil, and ? Cape St. Vincent[†], Spain; St. Vincent, Cape Verde Islands, 5–20 fath., collected by Crossland.

CRISIA.

When this paper was almost finished Harmer's valuable 'Siboga' Report was published, and as I was not sure how far I agreed with him upon some points, this genus again received further examination, confirming most of the conclusions previously arrived at.

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[*] See page 15.

[†] I wrote asking Mr. Kirkpatrick if there was any possibility of the British Museum specimen from "Cape St. Vincent, Spain," having come from St. Vincent, Cape Verde Is., and he kindly replied that it was 'Rattlesnake' material, purchased through a dealer, and that 5 fath. looks like offshore at Cape Verde, not St. Vincent, Spain, and that there was probably a sale catalogue mistake.

The ovicells are generally of three forms [*] :—

1st. Those that are free, with the oœciostome on the dorsal surface, as *Crisia Edwardsiana*, d'Orb., *C. biciliata*, MacG., *C. howensis*, MacG., *C. kerguelensis*, Busk, *C. inflata*, Waters, *C. cuneata*, Maplestone.

2nd. Those with a pomiform ovicell, as *C. aculeata*, Hass., *C. eburnea*, Hincks (pars), *C. elongata*, Harmer (M. Ed. ?), all of which have an opening with more or less of a slit and no pronounced tube; then *C. conferta*, Busk, and *C. sertularoides*, d'Orb., have a tubular oœciostome. A funnel occurs in *C. conferta*, Busk, which in many other respects corresponds with *C. elongata*, Harmer.

3rd. There are a number with pyriform ovicells, most of which seem to have a tubular oœciostome, as *C. tubulosa*, Busk, and *C. fistulosa*, Heller, with large wide zoœcia about 0·1 mm. or more in the aperture. *C. operculata* [†], Rob., *C. pacifica*, Rob., *C. maxima*, Rob., *C. pugeti*, Rob., have also elongate pyriform adnate ovicells, but the zoœcia are smaller, being about 0·07 mm.; then *C. ramosa*, Harmer, *C. Holdsworthii*, Busk, *C. eburneo-denticulata*, Smitt, *C. tenuis*, MacG., *C. cribraria*, Stimp., *C. geniculata*, M. Ed.

We can only give typical shapes of the ovicells as there is a certain amount of variation—for instance, I have *C. denticulata*, from Roscoff, sent to me by Joliet, in which there are several long ovicells (Zeppelin form) almost tapering at the end (see Busk, Cat. Mar. Poly. pt. iii. pl. 4. figs. 2, 3), whereas from the same colonies there is one with a shorter ovicell and flattened distal end. A colony of Harmer's *elongata* from the 'Siboga' Expedition shows considerable variation of the ovicells, so that they might be called pyriform, pomiform, or wider. Canu [‡] gives the photograph of the fossil *Crisia Corbini*, Canu, with a very large and wide ovicell, about double the width of the branch, with the end flat.

Jullien and Calvet [§] say that they consider the "formules algébroides" introduced by Smitt, and followed by Harmer, with one slight simplification, to be valueless, and these have never appealed much to me, for in description we must try and give the usual or typical characters, rather than take an individual in such a genus. However, there may be cases where such a formula may be useful, as, for instance, using it instead of an extra figure or in sending particulars to a correspondent. The formula has, however, been made unnecessarily puzzling by the use of the plus (+) sign, where plus is not really meant, for the number of zoœcia in a branch is first given, then where a new branch occurs is indicated, but this is not a plus, it is not additional, unless the subbranching zoœcia are first mentioned separately; and by putting a comma instead of the + the disconcerting "algébroide" appearance is done away with. We thus give the number of zoœcia, say 9, and show that the new branch occurs after the second zoœcia, and whether the branch is on the right or the left by the position of *r*. There is, of course, not the objection to brackets that there is to the plus, but it is more easily printed with a colon. A specimen from the Cape Verde Island collection reads:—

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[*] "Bry. from Zanzibar," Proc. Zool. Soc. 1914, p. 840.

[†] Some of Robertson's species are only judged from the figures, and this is the case with *C. tenuis*, MacG.

[‡] "Bry. des Terrains Tert. des Environs de Paris," Ann. de Paléont. vol. ii. (1907) p. 104, pl. xii. fig. 6.

[§] Jullien et Calvet, Bry. prov. des Camp. de l'Hirondelle, p. 109 (1903).

$$\begin{array}{l} 9,\ r_2\ :\ 9,\ {}_2r\ :\ 12,\ {}_2r,\ \times\ . \\ \quad | \\ 18,\ {}_1r,\ or_3,\ {}_5r,\ r_4,\ \times\ . \\ \quad | \\ 12,\ {}_1r,\ or_3,\ \times\ . \end{array}$$

This is a piece near the growing end, whereas at the base there are a number of internodes without zoœcia, or very few, before the typical internodes are formed. The example formula only deals with three branches, while many colonies will have fifty, and for some colonies a large sheet of paper is required, though the main features of a hundred colonies might sometimes be given in a few lines. It should be noticed that the growing branch frequently contains a larger number of zoœcia than other branches. A further complication in the formula occurs in Harmer's last paper, a branch on the right has *r* and a small figure below, whereas a branch on the left has a large figure and a small *r* above, but, although it occurs throughout, it must surely be a printer's error.

In giving the measurements of the distance from zoœcia to zoœcia it, of course, must not be supposed that there is no variation, but if mature branches are taken, though not the lower zoœcia on a branch, then it will usually be found that the variation from the average is but slight.

CRISIA TUBULOSA, *Busk*. (Plate 3. fig. 1.)

Crisia tubulosa, Busk, Cat. Mar. Polyzoa, pt. iii. p. 7, pl. vi. A. figs. 3, 4 (1875).

In the Boa Vista specimens the zoœcial tubes expand at the end, the aperture measures about 0·12 mm., which is a trifle smaller than the British Museum specimen, and the zoœcial tube is free for a considerable extent. The ends of the zoœcia are 0·5 mm. apart, and except in the lower internodes there are more zoœcia than given by Busk, sometimes as many as 16. The branches arise from the second, third, or fourth pairs. The ovicells are elongate pyriform, to some of which there is a tube without any funnel, but other ovicells show no tube. In the British Museum specimens there is a slight funnel. The aperture of the ovicell tube is about 0·08 mm. There is usually a branch on each side near the base of the ovicell. The bases rami are long—that is, they reach to the next zoœcium below.

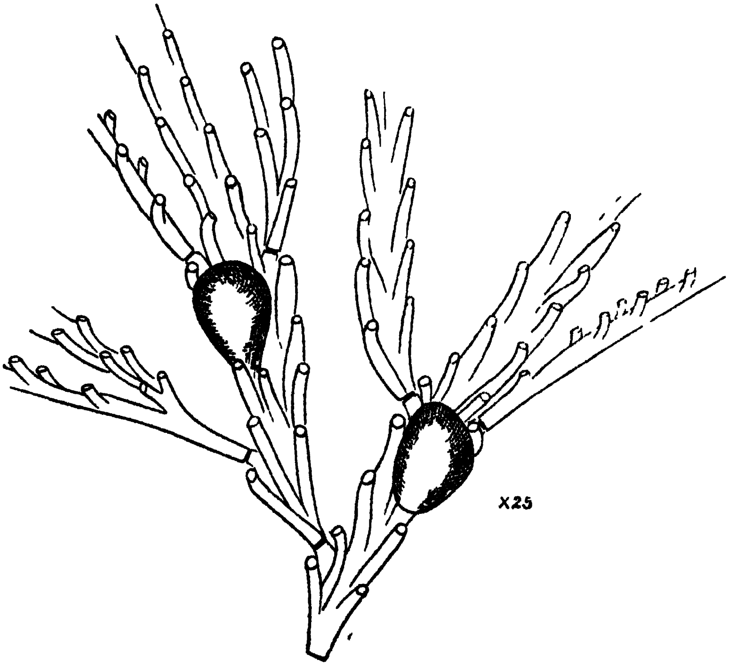
This is much like *C. pacifica*[*], Robertson; but from Dr. Alice Robertson's figure the distance from zoœcium to zoœcium is only about 0·33 mm., so that it is a more slender species than *tubulosa*, Busk. *C. pacifica*, Rob., *C. maxima*, Rob., *C. pugeti*, Rob., all seem closely allied.

Loc. Cape Verde Islands (*Busk*); and Boa Vista, Cape Verde Islands, collected by Crossland.

CRISIA DENTICULATA (*Lamarck*), *M. Edw.*, var. VERDENSIS, nov. (Text-fig. 2.)

There are several colonies from the Cape Verde Islands which are about 12 mm. long, forming close tufts much less straggly than is usually the case in *Crisia denticulata*, as the branches very soon have the mature form, and this may be the case after one short internode, whereas frequently in

Fig. 2.



Crisia denticulata (*Lam.*), var. *verdensis*, nov.

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[*] "Cyclostomatous Bryozoa of the West Coast of N. America," Univ. of California, Pub. Zool. vol. vi. (1910) p. 242, pl. 20. figs. 16, 17.

C. denticulata there are a series of short internodes before gradually becoming normal—however, this may be only a character of local importance. There are generally 7–9 zooecia in an internode, the branches usually commence after the first or second zooecium on that side, being alternate where there is no ovicell, with one branch to each internode, followed in the next internode by one on the other side. In the internodes with an ovicell there is usually a branch after the first zooecium or near it, and a few zooecia further up is the ovicell, as well as a new branch on one or both sides near to it, corresponding with the branching and ovicell described by Harmer in his *C. elongata*[*]. The ovicell, though not as short as in Harmer's figured specimen, is short and pomiform, but does not spread out at the distal end as much. It has a slit or oval opening in the distal end of the ovicell as described by Harmer for both *elongata* and *denticulata*.

The branches are fairly straight, with sometimes a slight sigmoid curve as may also be found in *C. denticulata*. The zooecial aperture is about 0·06 mm., the distance from zooecium to zooecium is about 0·26 mm., the joints are black. The denticle on the outer side of the zooecium is a most inconstant character in this and other species, for some internodes may have it strongly marked, while it is quite absent in others.

It would seem that round *denticulata*[†] we have a group including probably *C. acropora*, Busk, *C. sinclairensis*, Busk, *C. elongata*, M. Edw., *C. elongata*, Harmer, *C. serrata*, Waters. Whether we consider them as species or varieties I cannot think that the form I figured as *C. elongata*[‡], believing it to be the form described by Milne Edwards, is less entitled to a distinct position than the others. Its internodes are remarkably straight, whereas Harmer describes his as usually with a sigmoid curve. I suppose that about 100 internodes of the form figured were examined, all straight and long with numerous zooecia, and only one branch growing near the distal end. The base of the branches, both main and lateral, of the Zanzibar *elongata* is very broad, about 0·13 mm., but as this is not much broader than in *C. denticulata* much importance cannot be attached to it. In my paper "On some Species of *Crisia*,"[§] I have referred in more detail to Harmer's *C. elongata*, and indicated that two queried specimens may have influenced him to make a comparison with my *elongata*.

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[*] "Polyzoa of the 'Siboga' Expedition," Ent., Ctenost. & Cyclos. p. 96 (1915).

[†] The specimen of *C. denticulata* in the 'Challenger' collection from St. Paul's Rock, Chall. Rep. Polyzoa, Pt. II., p. 4, pl. 2. fig. 3, has short ovicells without any tubular ooeciostome, the lower joints are black, and it is somewhat like Harmer's *C. elongata*. The specimen from Macclesfield Island, Tristan Da Cunha, has the joints light, the basis rami is not wedged in, and it does not seem to be *denticulata*. The specimen from Cape York has fairly straight internodes with the branches placed high, and is not unlike my *C. elongata*.

[‡] "Bry. from Zanzibar," Proc. Zool. Soc. 1914, pl. 1. figs. 3, 4 (1915), and see Ann. Mag. Nat. Hist. ser. 8, vol. xviii. (1916) p. 474.

[§] Ann. Mag. Nat. Hist. ser. 8, vol. xviii. (1916) p. 474.

The variety *verdensis* has comparatively short regular internodes, few branches in the internodes where there is no ovicell, black joints, base of branch about 0·08 mm., most of the bases rami are wedged in, while others are longer; though, as some of these characters may not be very important, *verdensis* and *elongata* may be moderately closely allied. On the other hand, the Cape Verde Islands specimens of *verdensis* are much like *C. sinclairensis*, Busk. At any rate, *verdensis* has not the long straight internodes with one branch to each, as in what Busk and I have considered to be *elongata*, M. Edw.

Loc. Boa Vista, Cape Verde Islands, 5–20 fath., collected by Crossland.

CRISIA SIGMOIDEA, *Waters*.

Crisia sigmoidea, Waters, Ann. Mag. Nat. Hist. ser. 8, vol. xviii. (1916) p. 476, pl. 16. figs. 9, 10.

Crisia denticulata, Waters, "Bry. of the Bay of Naples," Ann. Mag. Nat. Hist. ser. 5, vol. iii. (1879) p. 269, pl. 23. fig. 2.

There is one piece, from the Crossland Cape Verde collection, which I think is this species. The zoarium is broad, with the ends of the zoœcia free projecting upwards, the ends of the zoœcia are about 0·28 mm. apart, and the zoœcial apertures are about 0·06–0·07 mm. wide. The joints are light, and the base of a branch is about 0·1 mm. wide, occurring after the second or third zoœcium on that side, with another branch on the other side a few zoœcia further up. Unfortunately there is no ovicell, and the *C. sigmoidea* and *C. conferta*, Busk, are very similar, so that without an ovicell determination is difficult, but the type-specimen of *C. conferta* is slightly wider than *C. sigmoidea* and at the same time the basis rami is wider, being about 0·13 mm. in *conferta*. The ovicells of the Mediterranean *sigmoidea* do not show any tubular oœciostome, whereas the funnel-shaped oœciostome is very marked in *conferta*.

This differs from *C. denticulata* and the *C. elongata*, Harmer, in having light joints, but the position of the branches is very similar to Harmer's *elongata*.

Loc. Naples, Rapallo, Villefranche-sur-Mer, Oran (Algiers). Cape Verde Islands, collected by Crossland.

CRISIA VINCENTENSIS, sp. nov. (Plate 3. figs. 2, 3.)

This is a form which has been difficult to place, for although there are several small specimens an ovicell was only found in one case, and of such an unusual form as to raise the question as to whether it is abnormal. It is broad throughout, as though two zoœcia might have been forming ovicells which became agglomerated. At first it was thought to be *C. eburnea*, and probably the variety *laxa*, Busk.

The lower branches usually start from below the aperture of the first zoœcium—that is, from the side of the first zoœcium,—while in older parts the new branch arises above the aperture of the first zoœcium. In *C. eburnea*, Hincks, there is some irregularity as to the branches starting from the first or second zoœcium, though it is most frequently from the first.

In *C. vincentensis* there are usually 7 zoœcia in an internode, the zoœcial aperture is 0·05–0·06 mm., the oœciopore is 0·03 mm. without any funnel; the branches are about 0·12 mm. wide, the distance from zoœcium to zoœcium is about 0·26 mm., the base of a new branch is about 0·07 mm., and the joints are light. The basis rami differs from that of *C. eburnea* in being longer, sometimes reaching to the next zoœcium, or it may stop a little short of this, whereas generally the basis rami in *eburnea* is short with what I should call the graft character. A 'Challenger' specimen of *C. eburnea*, var. *laxa*, in the British Museum from the Busk collection has a large, long, adnate ovicell much raised at the distal end with the oœciostome contracted, so that it is much wider than deep as in the *C. eburneo-denticulata* figured by me * from West Greenland, and on this account the present form is not placed under *laxa*.

Harmer †, with a query, places *C. eburnea*, var. *laxa*, as a synonym of *C. kerguelensis*, Busk, but the specimen alluded to in the British Museum, with the attached ovicell, proves that it is not the *C. kerguelensis*, which Harmer figures with a free ovicell, having a tubular oœciostome on the dorsal surface.

A new name is given with considerable hesitation to the present Cape Verde specimens.

C. vincentensis has about 12 pores in each square 0·1 mm., *C. eburnea* and *C. fistulosa* have fewer, *C. ramosa* about 5.

TUBULIPORA PULCHRA, *MacGillivray*, var. nov. (Plate 3. figs. 8, 9.)

Tubulipora pulchra, MacG., "Descr. of new or little-known Polyzoa," pt. vii. Trans. & Proc. R. Soc. Vict. vol. xxi. (1885) p. 95, pl. 2. fig. 1; Robertson, "Cyclost. Bry.," Univ. of California, Pub. Zool. vol. vi. (1910) p 250, pl. 23. figs. 32–35.

Tubulipora fimbria, var. *pulchra*, Waters, Ann. Mag. Nat. Hist. ser. 5, vol. xx. (1887 p. 258, pl. 7. figs. 1–3.

The Cape Verde Islands specimens have the zoœcial tube much larger (0·14 mm.) than those from Port Jackson, Australia (0·7 mm.), and it may be necessary to consider them as a variety. Apparently the specimens examined by Dr. Alice Robertson are coarser than those from Australia, but not so large as the present form.

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* Ann. Mag. Nat. Hist. ser. 8, vol. xviii. (1916) pl. 16. figs. 4, 5.

† "Polyzoa of the 'Siboga' Expedition," Ent., Ctenost. & Cyclost. p. 105 (1915).

In the colonies from the Cape Verde Islands the young branches are narrow with only a few zooecia and frequently anastomose, though ultimately forming a wide spreading growth. They have evidently grown on a calcareous seaweed. *T. organizans*, d'Orb., sent to me by Jullien from Cape Horn, has similar attachments, and Harmer mentions them in *T. plumosa*, W. Thomp. It is possible that the species under consideration should be called *T. organizans*, d'Orb.

Loc. Victoria (*MacGillivray*), Port Jackson (*Waters*); Southern California, San Diego shore, 11–32 fath. (*Robertson*); St. Vincent Harbour, Cape Verde Islands, 10 fath., collected by Crossland.

TUBULIPORA LAMOUROUXII (*Audouin & Savigny*), *Waters*. (Plate **3**. figs. 4, 5, 6, 10, 11.)

Proboscina Lamourouxii, Aud., "Descrip. de l'Egypte," Hist. Nat. p. 236, pl. 6. fig. 5 (1826).

This occurs as a narrow band, with very long zooecia on each side, showing a certain amount of regularity as in *Idmonea*, or it may spread in opposite directions with two oval subcolonies (figs. 4 *a* & 10 *a*), or even spread out in a flabelliform manner, and in one of these the ovicell has a distinct purple colour in the dry state, so that at first it was taken for *T. liliacea* (Pall.), Harmer.

The zooecia are very exceptionally small, having the aperture about 0·5 mm., and the projecting portion of the zooecial tubes show no pores. The ovicell is central, forming a raised inflation with a simple ooeciostome tube, about 0·03 mm. The dorsal surface is very characteristic, having raised ridges curved from the median line, and along these ridges there is a row of small pores for the attachment (fig. 5).

No *Tubulipora* has been described with so small an ooeciostome tube, and in all the cases referred to by Harmer, with the exception of *T. flabellaris*, Fabr., the ooeciopore is larger than the zooecial orifice, whereas here it is smaller. Harmer * says the ooeciostome in *T. liliacea* is larger than the orifice of a zooecium, mentioning *T. phalangea*, Couch, as about the same size, in *T. aperta*, Harmer, as larger than the zooecial orifice, in *T. plumosa*, W. Thomp., as also larger, while in *T. flabellaris* it is somewhat less than the diameter of the zooecial orifice. Dr. A. Robertson † says that the ooeciostome in *T. occidentalis* is smaller than the aperture of a zooecium.

I met with a few cases of some very delicate tubes, three or four starting from near the same centre, and these were taken at first for an unknown form (Pl. **3**, fig. 7 juv.), but some young forms of *T. Lamourouxii*, with primary, convinced me that young forms with long erect tubes give much this appearance. Looking down on the tubes they are so much foreshortened that it is impossible to give satisfactory figures, and this remark applies also to the oœciostomes of fig. 4.

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* "On the Development of *Tubulipora*," Quart. Journ. Micr. Sc. vol. xli. n. s. p. 91.

† "Cycl. Bry. of the West Coast of N. America," Univ. of California, Pub. Zool. vol. vi. (1910) p. 249, pl. 22. figs. 29–31.

The discovery of this species, placed by Audouin in his genus *Proboscina*, a name adopted for a genus by d'Orbigny and others, is most important, for some authors, especially paleontologists, have considered that in the Stomatoporidæ, *Stomatopora* should be used for uniserial adnate forms, while *Proboscina* would include multiserial adnate forms. Undoubtedly the name *Proboscina* will have to be entirely dropped, and, while I think that *Stomatopora* will have to include many forms which are more or less multiserial, and that some things described as *Proboscina* will fall into *Tubulipora*, I am not prepared to state that all will find their places in these two genera; however, if a generic division is required for many now known as *Proboscina* there is the genus *Criserpia* * of H. Milne Edwards in which these can find a home †. Milne Edwards proposed to place all the known Cyclostomata in the "family" Tubuliporidæ, but we now see that many families as now understood were included, though until we understand more about the most important genus *Stomatopora* both as to its primary attachment and ovicells we cannot speak with any certainty concerning the group in question.

Miss Jelly and others have considered that Savigny's figures of *Proboscina Boryi* and *P. Lamourouxii* represented the same species, but in this I cannot agree, for in the figures the difference in size of the zoœcia is very marked.

Loc. Savigny's specimens were probably from the Red Sea or Mediterranean; St. Vincent Harbour, Cape Verde Islands, 10 fath., collected by Crossland.

TUBULIPORA INCRASSATA (*Smitt*), *Waters*. (Plate 3. fig. 7.)

Proboscina incrassata, Smitt, "Krit. Fört. öfver Skand. Hafs-Bry." Öfv. Kongl. Vetensk.-Ak. Förh. 1866, pp. 402, 458, pl. 5.

Tubulipora incrassata, Waters, "Bry. of the Bay of Naples," Ann. Mag. Nat. Hist. ser. 5, vol. iii. (1879) p. 272.

? *Proboscina Boryi*, Aud., Descrip. de l'Egypte, Hist. Nat. p. 236, pl. 6. fig. 4 (1826).

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* "Mémoire sur les Crisies," &c., Ann. Sci. Nat. 2me sér., Zool. ix. (1838) pp. 193–238. The importance of this paper has not always been fully appreciated, for here the Cyclostomata were divided from the Cheilostomata, though under other names, and since then there has been much elaboration. Audouin and Milne Edwards,[1] in 1828, separated the Bryozoa as "family" 4, meaning by this what we should now call a class. Although several zoologists had, for many years, realized that a separation of zoophytes should be made, they were the first to make it. To have shown not only that there was this class, but also to have realized the large divisions of Cheilostomata and Cyclostomata shows what good pioneer work Milne Edwards gave us.

[[1] Audouin et Milne Edwards, "Résumé des recherches sur les animaux sans vertèbres faites aux îles Chausey," Ann. Sci. Nat. vol. xv. (1828) p. 18.]

† Ann. Sci. Nat. vol. xv. (1828) p. 41.

There are some specimens of *Tubulipora* growing irregularly in a band-like form, with large zoœcia, the zoœcial aperture being about 0·14 mm., whereas in *T. Lamourouxii* the aperture is only about 0·05 mm. A young specimen of *T. Lamourouxii* (Pl. 3. fig. 7, juv.), growing on the present species shows the great difference in size. There are in the interior of the zoœcia a few pin-head spines, and in one zoœcium, not very far down, there is a row of short teeth. In a specimen from Naples there is an anterior ovicell spreading among several zoœcia, with a short tubular oœciostome, about the same diameter as a zoœcium, without any funnel.

I do not consider that the *Stomatopora incrassata*, Hincks, is the *Tubulipora* (*Proboscina*) *incrassata*, Smitt, nor am I sure that the form described by Smitt in 1871 * is the same species as he originally described. Without a considerable amount of material it is difficult to decide whether to provisionally retain Smitt's name or to give a new one, as it is evident that there has been some confusion. D'Orbigny first gave the name without figures, and the description is insufficient.

There is a certain amount of resemblance to *Filisparsa tubulosa*, Busk, from Naples, which, however, grows free or only very slightly attached, and has an oœciostome with one axis, usually the transverse, much the longer, with an irregular funnel as in *T. aperta*, Harmer. The zoarium spreads out slightly towards the distal end without being flabelliform, and although the zoarium does not expand as much as in Harmer's specimens, it would seem to be the same as *aperta*. Harmer, in his 'Siboga' Report, p. 143, says that *T. aperta* may possibly be the *Hornera tubulosa*, Busk.

Loc. Naples. St. Vincent Harbour, Cape Verde Islands, on clinkers, collected by Crossland.

LICHENOPORA IRREGULARIS (*Johnson*), *Norman*. (Pl. 4. figs. 2, 3, 5, 6, 7, 8.)

Radiopora irregularis, J. Yate Johnson, "Cyclost. Bry. from Madeira," Ann. Mag. Nat. Hist. ser. 6, vol. xx. (1897) p. 63.

Lichenopora irregularis, Norman, "Poly. of Madeira and neigh. Islands," Journ. Linn. Soc., Zool. vol. xxx. (1909) p. 282.

There are several zoaria growing on a large stone, brought up by a diver from off St. Vincent, Cape Verde Islands, and a small piece on a clinker from St. Vincent Harbour.

The very thin lamella is closely attached to the stone, and is more or less circular, quite independent of the outline of the subcolonies; the central subcolony is circular or oval, while the outer ones are lobulate or often form "subtriangular lobes" with uniserial zoœcia, and in these uniserial forms ovicells have been found. There are also various similar colonies, which from their general appearance seem as if they should be united, but they have bi-multiserial rays throughout the colony (Pl. 4. fig. 1) with subcolonies somewhat larger than those of the uniserial forms (figs. 2, 8), and this bi-multiserial form is provisionally called var. *composita*.

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* Öfvers. Kongl. Vetensk.-Ak. Förh. 1871, p. 1119.

Returning to the uniserial forms it is in these that the ovicells have been found, and the zoarial growth is similar to that of *Radicopora Francquana*, d'Orb.[*]

The central depressed region of each subcolony has large pores (about 0·07 mm.) about the size of those of the zoœcia, whereas the pores between the rays are usually smaller. The inner zoœcia of a ray are the most raised, whereas in var. *composita* there is very little difference—in fact, most seem cut off nearly straight, without being apparently worn; in this uniserial form the zoœcia are well raised, and especially near the edge of the colony the spinous processes are more pronounced than in the variety. In the British Museum specimen from Madeira[†], in the Norman collection, most of the zoœcia show a blunt spinous process at the outer border and occasionally on both the inner and outer, also the internal pin-head spines in the cancelli are very small and rather rare. In one colony, from Cape Verde Islands, there are two ovicells, which are very narrow and interdigitate in narrow bands between the rays (figs. 2, 6). The surface of the ovicell has numerous fine perforations. Another colony has a very deep pit in the centre of several of the subcolonies (fig. 5), but, on carefully focussing to the base of one pit, the narrow bands of a similar ovicell are seen, so that we are looking upon the upper part of an ovicell now at the bottom of this pit, and a zoarial growth must have taken place subsequent to the formation of the ovicell, but whether it indicates a regular second layer it is impossible to say. In one zoarium, in the centre of a subcolony, the base is found of an ovicell in formation, which is smooth and imperforate, proving that in the case previously mentioned we were not looking on the base of an ovicell at the bottom of the pit. In the section of another *Lichenopora* I have seen an ovicell in two stories—that is, one ovicell above another.

Harmer[‡] describes and figures a similar ovicell in what he calls *Lichenopora novæ-zelandiæ*, Busk, but it is unfortunate that he should have taken the name *novæ-zelandiæ* apparently because it was published a page sooner than *L. Holdsworthii*, Busk, for this latter is well described from characteristic specimens found in Ceylon. On the other hand, the description and figure of *novæ-zelandiæ* were not very satisfactory, and among the specimens which Busk so named in his collection there seem to be more than one species. I have some specimens which have always seemed to me to be this species, and one from New Zealand was sent to me so determined, also the British Museum specimens have been looked through more than once, without finding reason for change of opinion. Apparently Busk did not figure the specimen he was describing—in fact, the figure is from a badly preserved specimen; whereas he had in his collection specimens, so named, of what I have identified as *L. novæ-zelandiæ*. It is a small form in which the zoœcial tubes of the much raised inner zoœcia of the rays meet or nearly meet in the centre, forming when there is no ovicell a very depressed inverted cone. These have a raised flat ovicell * over the centre with most minute perforations and a bordering ridge; besides the cancelli are frequently formed with bars across, as in *L. radiata*, Hincks, and, although there are some "pin-head" spines in the cancelli and zoœcia, they are not very frequent, whereas in *L. Holdsworthii* the round cancelli are very regular, with very numerous large pin-head spines. In my specimens of *L. Holdsworthii*, in two cases, there are hollow grooves in the interradial spaces, and in other places on the central wall, which seem to relate to the formation of an ovicell such as that figured by Harmer (*loc. cit.* fig. 11).

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[*] Pal. Franç. pl. 782. figs. 3–8.

[†] In one case the ovicell only throws out arms on one side of the subcolony. There are some deep pits as described in the Cape Verde Islands specimens.

[‡] Polyzoa of the 'Siboga' Expedition, pt. i. p. 155, pl. 12. fig. 11 (1915).

I have a large number of *Lichenoporæ* with ovicells, and, when writing my short paper † on them, much time was spent in comparing the Natural History Museum types and specimens. Since then I have had some additions to my collection, and the Museum has received several valuable collections, such as Busk's and Hincks's, but on the whole it seems that what I then said is supported. My paper was written at a time when hardly anyone took any notice of the ovicells, in fact they were generally ignored; but certain types of ovicells were indicated, and whether the identifications will ultimately stand was a matter of secondary importance, though I am unaware of any reasons for changing the names then used. I showed that there was the flat type of ovicell as in *L. novæ-zelandiæ*, the raised, rounded, dome-shaped type with trabeculæ over the wall as in *L. echinata*, McG., and *L. victoriensis*, Waters, and, lastly, the ovicell spreading up to the rays as in *L. californica* (Busk) Waters. I stated that this should be considered as the species of Busk, as there was some doubt as to d'Orbigny's description, and Harmer, in calling attention to the biserial rays of Busk not being indicated by d'Orbigny, does not seem to have remembered what I had already said. However, the question of uncertainty through Busk's species being bi- to multiserial has no importance now, as I have a specimen from Western Port, Victoria, with uniserial rays and an ovicell as figured ‡ by me, and another from the same locality with biserial rays and a similar ovicell. The question of uni- and biserial rays has not only broken down as a generic character, but also in several cases as a specific one. All the same the *Lichenoporæ* have yet to be brought into order, and to do this we require more spirit-specimens; but to place as synonyms what I considered as *L. novæ-zelandiæ*, Busk, *L. Holdsworthii*, Busk, and *L. victoriensis*, Waters, does indeed seem retrograde. Harmer's 'Siboga' specimens must be called *L. Holdsworthii*, Busk [*].

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* "Bry. New South Wales, etc.," Ann. Mag. Nat. Hist. ser. 5, vol. xx. (1887) pl. 7. fig. 8.

† "On the Ovicells of some *Lichenoporæ*," Journ. Linn. Soc., Zool. vol. xx. (1888) pp. 280–285.

‡ "Bry. New South Wales, etc.," *l. c.* p. 261, pl. 7. fig. 8.

Since I wrote on the ovicells, among others, two specimens from Ceylon, named by Busk *L. Holdsworthii*, have been added to the National Collection. The central part is somewhat depressed with an ovicellular wall covering it, and the rays extend into the ovicell; by the side of this there is an oœciostome tube, and on one of the specimens at a higher level there is an ovicell spreading in and out between the rays.

These Cape Verde specimens of *L. irregularis* are not, as Norman supposed, what I called *Radiopora pustulosa* [†], d'Orb., from Naples, each subcolony of which has some multiserial and some uniserial rays, and the subcolonies are much larger than those of the Cape Verde Island forms. The specimens alluded to, from Naples, are not closely attached, nor were Peach's *L. meandrina*. Although unable to see any material difference between the recent and fossil *R. pustulosa*, there is some uncertainty in identifying a fossil about which we know little, and therefore it would have been a safer course to have named the recent one *L. neapolitana*, as it does not seem to be the same as *L. hispida*, Flem. The specimens of *L. meandrina*, Peach, in the Nat. Hist. Museum from Busk's and Hincks's collections, have much smaller subcolonies than what I called *pustulosa*, d'Orb., and the zoœcia are 0·07–0·08 mm., while the cancelli are about 0·06 mm.—that is, smaller than in *pustulosa*, where they are about 0·1 mm., with the zoœcia about 0·09 mm.

In the Museum specimen of "*meandrina*" the subcolonies are often very elongate, instead of circular, and there are more definite serial ridges than in the solitary *L. hispida*, Flem., and we may certainly doubt the advisability of considering the composite form a variety of *hispida*. Peach's figure and description of *L. meandrina* correspond more with the Mediterranean *pustulosa* than do the Museum specimens, which are not from Peach's collection. However, I think we have as separate species *L. irregularis*, Johns., *L. pustulosa*, d'Orb. (Waters), and *L. meandrina*, Peach. The ovicells are unknown in the last two species. Other composite species are *L. pristis* [‡], MacG., *L. magnifica*, MacG., *L. bullata*, MacG., and several fossil ones are known as *L.* (*Radiopora*) *formosa* [§], d'Orb., *L.* (*Radiopora*) *Francquana* [‖], d'Orb.,

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[*] There is, however, a small specimen from between Nusa Besi and N.E. point of Timor (St. 282) with long erect biserial rays, which may almost be said to be small bundles of rays, and the central zoœcia are very irregular. This I cannot consider to be the same species as the other so-called *novæ-zelandiæ*.

[†] Pal. Franç. pl. 649. figs. 1–4.

[‡] Trans. Roy. Soc. Vict. vol. xx. (1883) p. 126.

Pal. Franç. pl. 782. figs. 1, 2.

[‖] Pal. Franç. pl. 782. figs. 3–8.

L. (*Radiopora*) *multistellata*[*], d'Orb., *L. conjuncta*[†], Mich., *L. cumulata*[‡], Mich., *L.* (*Multitubigera*) *micropora*[§], Reuss, *L.* (*Multitubigera*) *gregaria*[||], d'Orb., *L. suecica*[¶], Hennig.

The early stage of *Lichenopora* is flabelliform and is like that of *Tubulipora* (say, *flabellaris*, Fabr.), but it soon completes the circle and then the flabelliform growth can only be seen by examining the under side. Now clearly in a colony of *L. irregularis*, *L. meandrina*, and *L. pristis* there is only one primary, and the new subcolonies may be said to bud out from the older ones (see figs. 1, 2, 3, 4, 5), and this requires further study with sections. It does not seem strictly correct to speak of these as confluent, as is usually done. There are also many cases of *Lichenopora* where the two colonial disks partially coalesce : for instance, I have specimens of *L. verrucaria* where the touching lamina of two disks form one growth, as well as some of the adjacent zoœcia uniting. In *Lichenopora boletiformis*[**], d'Orb., we find the same thing, and also one colony growing on the top of another, which also occurs in many other cases—as, for example, *Discosparsa marginata*, d'Orb. *Lichenopora* with multiserial rays was separated from *Discocavea* with uniserial rays, but most recent workers have recognized that the difference of the rays cannot be retained as a generic character, though usually useful specifically, while some both of the confluent and simple species show that even specifically the character may not always be of value. The type is *Lichenopora turbinata*[††], Defrance, also photographed by Canu[‡‡], which, although with but a small attachment, has been considered by Pergens and Canu to belong to *Lichenopora* as now generally understood. As described by d'Orbigny and by Canu *L. turbinata* has cancelli. *Lichenopora* is not the only genus which forms round disks, and there are a number with the zoœcia radiating in bundles without pores between the rays. Many of these have been called *Defrancia*, others *Actinopora*, *Apsendesia*, *Pelagia*, &c. These Gregory[§§] would place partly in *Lichenopora* (having removed what has so long been considered *Lichenopora* to *Discocavea*) and partly under *Apsendesia*, considering that *Pelagia clypeata*, Lamx., was the same species as *Apsendesia cristata*, Lamx., but from Lamouroux's figure of *cristata* nothing can be made out; however, Michelin, Haime, and Gregory have given figures of what they believed was the *Apsendesia cristata*. Haime thought that the two genera must be united, while Gregory * considers that they should be united as one species, but since *Pelagia clypeata*, Lamx., occurs, from various localities, as a complete and mature species I cannot at present accept this view. Perhaps it would be most reasonable to retain *Defrancia*, but time will show, and in this group, in all cases with which I am acquainted, the ovicell is near the border of the zoarium.

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[*] Pal. Franç. pl. 649. figs. 5–7.

[†] Michelin, Icon. Zooph. p. 277, pl. 63. fig. 16 (1840-7).

[‡] *Loc. cit.* p. 319, pl. 77. fig. 1.

[§] Reuss, "Anth. & Bry. von Crosaro," Denk. Ak. Wien, vol. xxix. (1869) p. 259, pl. 36. fig. 15.

[||] *Loc. cit.* pl. 752. figs. 9, 10.

[¶] "Bry. Sver. Kritsystem," Lunds Univ. Årsskrift, vol. xxx. (1894) p. 35, pl. 2. figs. 33–36.

[**] Waters, "Cyclost. Bry. from Australia," Q. Journ. Geol. Soc. vol. xl. (1884) p. 695, pl. 31. figs. 20, 21.

[††] Dict. Sc. Nat. vol. xxvi. p. 257, pl. 4. figs. 4, 6 (1823).

[‡‡] "Bry. des terr. Tertiaires," p. 138, pl. 17. figs. 13–15, in Ann. de Paléont. (1907).

[§§] "Cretaceous Bry.," Cat. Fossil Bry. in Brit. Mus. p. 247 (1909).

In a specimen of "*Actinopora regularis*," d'Orb., which I collected from St. Croix, Switzerland, the locality from which d'Orbigny described it, there is fortunately an ovicell extending from one ray to the next and not very large. The ovicell was not previously known, and my specimen is as good as a co-type, and shows that it is not *Lichenopora* but *Defrancia*, if this name is retained.

For a long time, while progress was being made with the classification of the Cheilostomata, that of the Cyclostomata seemed most hopeless, but now that more is being learnt about the ovicells and other characters, there is every reason to hope that the collection and study of more species will make the classification more natural.

Harmer in his 'Siboga' Report, received after the above descriptions were written, considers that *Lichenopora* should be used for what we have so long understood by this name, and Pergens, Canu, and others have expressed the same opinion.

Loc. Madeira (*Johnson*, *Norman*); St. Vincent, Cape Verde Islands, collected by Crossland per diver.

LICHENOPORA IRREGULARIS, var. COMPOSITA, var. nov. (Pl. 4. figs. 1, 4.)

This is the bi-multiserial form mentioned as occurring on the same stone as *L. irregularis*, Johnson, and about which I have been in doubt as to whether the two forms should be united as one species. The subcolonies are somewhat larger than those of the uniserial form, and the zoœcia, usually without any spines, are less raised, but otherwise they seem similar.

FLUSTRELLA HISPIDA (*Fabricius*), *Gray*.

For synonyms see Miss Jelly's Catalogue, and add:—

Flustrella hispida, Prouho, "Recherches sur la larve de la *Flustrella hispida*," Arch. de Zool. Expér. et Géner. 2nd ser. vol. viii. (1890); Robertson, "Bryozoa," Harriman Alaska Exped., Proc. Wash. Ac. Sc. vol. ii. (1900) p. 331; Nordgaard, Hydr. and Biol. Invest. in Norwegian Fiords, p. 173 (1905).

Only a very small piece was found, but it was enough for certain determination. This is widely distributed in northern seas, and is common on the

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* "Jurassic Bry.," Cat. Fossil Bry. in Brit. Mus. p. 171 (1896).

British and North French coasts; and Dr. Alice Robertson reports it from California, but it has not been mentioned from the Atlantic or from the Mediterranean. Hincks describes a form from Victoria as var. *cylindrica*, but judging from my specimens from Port Phillip I should certainly not call it a variety of *F. hispida*, for it has spines regularly all round the zoœcium, which is not the case in the northern form, which also is a larger and more solid form.

Flustrella hispida has 23–27 tentacles.

Harmer * considers that the genus *Flustrella* should be retained.

Loc. Northern Seas; California; Boa Vista, Cape Verde Islands, 5–20 fath., collected by Crossland.

AMATHIA TORTUOSA, *Tenison Woods* (non *Busk*).

For synonyms see Waters, "Mar. Biol. of the Sudanese Red Sea, Bryozoa," pt. ii. p.243, pl. 24. fig. 5 (1910).

Dr. Harmer † has doubted the determination of this species from the Sudan, perhaps partly through my figures being merely outlines. I gave three very small figures of forms believed to be three species, so that a comparison could be made of the size and position, but merely to show these characters in question.

In *Amathia* the lower parts of the zoœcia are usually connate, whereas the upper part may be more or less free, varying in appearance according to the condition of the specimen and of the mount. My figure 5 of *A. tortuosa* (also figured by MacGillivray) is depicted looking down on the top of the zoœcia when the upper part is seen separated, giving naturally a short appearance, but it was advisable to show it in this position. The length of the zoœcia from Cape Verde Island are about 0·4 mm., with the lower half of the zoœcia connate and the upper free. With regard to my figure of *A. distans*, Busk, the scale was too small for it to be possible to show the ends in detail, but it will be seen that in two or three cases projecting zoœcia are shown, and this was more distinct in the original drawings, for though taken from actual specimens the size prevented their being more than diagrammatic in most respects; the length of the zoœcia is relatively the same as figured by T. Woods ‡, and surely if he had been speaking of the length of the zoœcia he would have said the length of the cells and not of "the pair of cells," and he meant the length of the group of the pair of cells. This unfortunate sentence of T. Woods has misled several authors, but the figure does not show long cells. My determination of the Sudan and Zanzibar

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* Polyzoa of the 'Siboga' Expedition, p. 40 (1915).

† Polyzoa of the 'Siboga' Expedition, Ent., Ctenos. & Cyclos. p. 68 (1915).

‡ "On the Genus *Amathia*," Trans. Proc. Roy. Soc. Victoria, vol. xvi. (1879) p. 90, fig. 6.

Amathiæ was made after prolonged comparison of the British Museum and 'Challenger' specimens, and I cannot think there is anything material to alter in what I then wrote.

In the Cape Verde Island specimens there are usually 14 pairs of zoœcia. The zoarium grows from a seaweed, and the free stolon when passing over the narrow branch of any part of the seaweed becomes attached across it, again growing free beyond it. Where the stolon is thus attached the zoœcia are arranged horizontally on each side of it, thus forming two lateral series without any sign of the spiral arrangement. From the front of the attached stolon, and in the middle of the group of zoœcia, one or two fresh erect branches arise, a mode of growth and branching quite unknown in *Amathia*, raising rather large questions

On the same seaweed were entangled pieces of *Amathia Vidovici*, Heller, but on careful separation the colonies were found to be quite distinct. The seaweed having been some time in spirit has entirely lost any colour it may have had, and resembles a figure I have before me of *Polyides rotundus*, Grev., which may by now be known by another name.

I followed MacGillivray in considering that *A. connexa*, Busk, was a synonym, although stouter; of this I am now doubtful, and in the determination of some of these spiral forms we are on rather uncertain ground. A specimen in the British Museum determined as *A. connexa* by Busk I found had the stem only 0·2 mm. diameter, which is much below Busk's measurement. *A. connexa* is the largest of these spiral forms with more or less free ends, then comes *A. tortuosa*, then *A. distans*, and there is also *A. Vidovici*, with the zoœcia much separated, but it may be the differences are not as important as now supposed. In *A. obliqua*, MacG., the ends are free, and even in *A. lendigera*, Lamx., a considerable part is often free; and while we usually find that the species with the zoœcia almost entirely connate have the two series also united, yet in *A. lendigera* the two series may sometimes be found almost unattached in the middle. We must remember that we are not quite sure what characters are of most value in *Amathia*. The Zanzibar *A. distans* has the ends of the zoœcia free as in *A. tortuosa*, and a small fragment from Sydney of what I have always considered to be *A. distans* has the zoarium and zoœcia the same size as those from Zanzibar and the ends are free.

Loc. New South Wales; Victoria; Red Sea; Cape Verde Islands, collected by Crossland.

AMATHIA VIDOVICI (*Heller*), *Waters.*

Amathia Vidovici, Waters, "Marine Fauna of Brit. East Africa and Zanzibar," Cyclos, Ctenos. & Endoprocta, Proc. Zool. Soc. London, 1914, p. 848, pl. 4. figs. 1, 2, which see for synonyms.

This is growing on the same seaweed as *A. tortuosa*, T. Woods. There are usually about 8–9 pairs of zoœcia (about 0·4 mm. long) in a short spiral near the joint, with the lower part connate, the upper part free, as in *A. tortuosa*; and this is the rule in *A. Vidovici* from other places, but a specimen from Genoa has the zoœcia more free—in fact, some of the zoœcia near the ends of the branches are quite free. From the stem there are a few radicles with digitiform processes. The stem is about 0·14 mm. in diameter, and there is a certain amount of variation in the thickness of the stems, but the piece measured from Zanzibar must have been abnormally compressed, as most are approximately the same as the present. I find that the piece sent to me by Joliet as *Serialaria semiconvoluta*, from Roscoff, has biserial zoœcia arranged in a spiral which is longer than that of *Vidovici*, being somewhat like *A. tortuosa*, and the zoœcia are much separated, so that many are quite free, which led me to think it was a modified form of *A. Vidovici*, but there is a little uncertainty as to what it should be called. We have seen that *A. tortuosa*, Woods, *A. distans*, Busk, and *A. Vidovici* are very closely related. I have a sketch of an *Amathia* in the British Museum, from the Ægean Sea, named *Serialaria lendigera*, 91. 71. 4378, which seems to be *A. Vidovici*.

Loc. Mediterranean; Bermuda (*Chall.*); Brit. East Africa; N.E. Coast, United States; Cape Verde Islands, collected by Crossland.

ZOOBOTRYON PELLUCIDUM, *Ehrenberg.*

For synonyms and localities see Waters "Bry. from Zanzibar," Proc. Zool. Soc. 1914 p. 849; and Journ. Linn. Soc., Zool. vol. xxxi. (1910) p. 243, pl. 24. figs. 12, 15.

The specimens from Boa Vista, Cape Verde Islands, correspond closely with those from Naples and the Red Sea.

As previously said, I think that *Zoobotryon* and *Bowerbankia* will have to be united. Harmer does not agree, as he thinks the zoarial characters are sufficient to warrant the separation, but the only difference is whether the branching is usually with two new branches or three, whereas in a closely allied genus, *Amathia*, there are considerably greater differences, without new genera being made. For example, *A. Wilsoni*, Kirkpatrick, an undoubted *Amathia*, has also three branches at a joint.

BOWERBANKIA PUSTULOSA (*Ellis & Sol.*) *Hincks*, var. ALTERNATA, var. nov.

Specimens from Boa Vista, growing on *Zoobotryon pellucidum*, Ehr., as well as on the supporting seaweed, and others from St. Vincent Harbour, 10 fathoms, are smaller than *B. pustulosa* *, Hincks. The stolon (0·04 mm.) is smaller, the zooecia (0·35–0·45 mm.) are shorter, and the gizzard is about 0·07 mm. in diameter. The zoarium is usually creeping, but small pieces are free, some of which may have been attached. From the creeping stolon the zooecia grow on the opposite sides, though not as a rule in pairs, but alternate in groups of four to ten (usually about ten); after a group there is a diaphragm, followed by a bare stolon for a moderate distance, and then the next group. A few branches grow at right angles to the main stolons, and then there is a diaphragm near the beginning of the new branch.

Var. ALTERNATA.

This is much like *B. gracillima* †, Hincks, but the stolon is smaller in the var. *alternata*, also the zooecia are smaller than those of typical *pustulosa*, whereas Hincks describes his *gracillima* with larger zooecia than those of *pustulosa*, though from his figure there does not seem to be much difference.

Wherever this may ultimately be placed, it seems safest to now call it var. *alternata*.

Loc. Boa Vista and St. Vincent Harbour, 10 fath., Cape Verde Islands, collected by Crossland.

BARENTSIA DISCRETA (*Busk*), *Kirkp.*

Ascopodaria discreta, Busk, Zool. Chall. Exp. vol. xvii. p. 44, pl. 10. figs. 6–12 (1886).

Pedicellina australis, Jullien (non Ridley), Mission Scientifique du Cap Horn, p. 13 (1888).

Barentsia discreta, Harmer, Polyzoa of the 'Siboga' Exp. p. 29, pl. 2. figs. 8, 9 (1915). As Harmer gives full references I have struck out mine and refer to his paper for synonyms.

I have previously mentioned that the connection of the pedicel with the polypide is subject to considerable variation, sometimes the rings mentioned by Busk are seen, but in other specimens there are none. This has been confirmed by Osburn. Asajiro Oka ‡ has described *Barentsia misakiensis* as closely allied to *Barentsia discreta*, which he, however, distinguishes by the number of tentacles, his species having 20–24, whereas Busk describes *B. discreta* as having 16–20 ; it, however, seems doubtful whether they should be separated, and Harmer also unites the two species.

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* Harmer, in his "Polyzoa of 'Siboga,'" p. 72, has, from my figure, doubted whether I had obtained *Bowerbankia imbricata* from the Sudan (Journ. Linn. Soc., Zool. vol. xxxi. (1909) pl. 25. fig. 8). But I made sketches of the three conditions of the zooecial chamber, and it was intended to be obvious that fig. 8 represented a zooecium in which histolysis had quite altered the polypide, but, nevertheless, in spite of these great changes having taken place, the shape of the zooecial chamber was not as yet at all altered. If the object had been to show a perfect zooecium a much more detailed figure would have been drawn, and certainly a little further explanation on my part would have avoided false conclusions. The figure merely represents any typical *B. imbricata*.

† Hincks, Brit. Mar. Poly. p. 525, pl. 75. fig. 6 (1880).

‡ "Sur la *Barentsia misakiensis*," Zoolog. Magazine, Tokyo, 1895, pp. 76–86, pl. 12. figs. 1–8.

Loc. Tristan da Cunha, 100–150 fath. (*Busk*) ; China Seas, 27 fath. (*Kirkpatrick*) ; Ceylon, India, Chile, Cape Horn, 40 met. (*Jullien*) ; Vineyard Sound and Buzzard Bay, Beaufort, N.C., and Tortugas Isl., Florida, 18 fath. (*Osburn*) ; 5° 28′ S.–134° 53′ E., 57 met. ; 1° 42′ S.–130° 47′ E., 32 met. ; Makassar, 0–32 met. ; Saleyer, 0–36 met. (*Harmer*) ; St. Vincent Harbour, Cape Verde Islands, from under stones, collected by Crossland.

PEDICELLINA CERNUA (*Pallas*), *Smitt*.

For synonyms see Miss Jelly's Catalogue, and add :—

Uljanin, "Anat. & Entw. Gesch. der *Pedicellina*," Bull. Soc. Imp. de Natur. de Moscou, 1870, pls. 5, 6; Harmer, "Life-Hist. of *Pedicellina*," Q. Journ. Micr. Sc. 1886, p. 239; Jullien, Mission du Cap Horn, Bryozoaires, p. 9 (1888); Seeliger, "Ungesch. Verm der Endoproct. Bry.," Zeit. Wissen. Zool. vol. xlix. (1889) pls. 9, 10; Levinsen, Zool. Danica, 'Mosdyr,' vol. iv. p. 96, pl. 9. figs. 18–29 (1894); Calvet, "Bry. Mar. de la Reg. de Cette," Trav. Inst. Zool. de l'Univ. de Montpellier, ser. 2, mém. 11, p. 94 (1902); Jull. & Calvet, Bry. prov. des Camp. de l'Hirondelle, p. 25 (1903); Norman, "Nat. Hist. East Finmark," Ann. Mag. Nat. Hist. ser. 7, vol. xi. (1903) p. 574; Osburn, "Bry. of Woods Hole Reg.," Bull. Bur. of Fisheries, vol. xxx. (1912) p. 213, pl. 18. figs. 3 *a–d*; Osburn, "Bry. of Tortugas Isl., Florida," Pub. Carnegie Inst. p. 185 (1914).

The specimens on *Scrupocellaria Bertholetti*, Hincks, from St. Vincent, Cape Verde, are about 0·4 mm. long, whereas British forms in my collection are about 1·6–2 mm. long.

Loc. Northern Seas ; British and French coasts, Mediterranean, Australia (*Kirkpatrick*) ; Senegal, Gulf of Guinea, Liberia, Egypt, Smyrna (*Jullien & Calvet*) ; Canary Islands (*Jullien*) ; Woods Hole Region (*Coburn*) ; Cape Verde Islands (*Jullien & Calvet*) ; St. Vincent, Cape Verde Islands, collected by Crossland.

EXPLANATION OF THE PLATES.

PLATE 1.

Fig. 1. ***Bugula dentata***, × 25. The tissues drawn dark are coloured a dark blue, and this coloration is specially marked in the growing tissue and tips of the tentacles.

2. ***Beania hirtissima***, × 25. Dorsal surface.

3. ***Scrupocellaria Macandrei.*** (*a*) Operculum, × 250; (*b*) seta, × 85; (*c*) base of seta, × 250; (*d*) mandible of lateral avicularium, × 250; (*e*) mandible of anterior avicularium, × 250.

4. Do. do. Avicularian chamber decalcified, × 250.

5. Do. do. Base of seta with muscles and lateral chitin pieces (*ch.*), × 250.

Fig. 6. *Scrupocellaria Macandrei.* Avicularium, × 100.
7. Do. do. × 85.
8. *Membranipora quadricornuta*, sp. nov., × 25. The distal spines usually stand erect, but some are given bent down to show the shape.
9. *Scrupocellaria tridentata*, sp. nov., × 85.
10. Do. do. Mandible fitting into the avicularium.
11. *Scrupocellaria Macandrei*, × 85. Decalcified, showing the position of the ovary (*ov.*) and the testes (*t.*).

PLATE 2.

Fig. 1. *Schizoporella trichotoma*, sp. nov., × 50.
2. Do. do. × 85. Operculum.
3. Do. do. × 250. Pores in decalcified membranes of the frontal surface of the zooecia, showing the larger and smaller rings on the inner and outer wall.
4. Do. do. × 12. Showing the primary zooecium.
5. *Schizoporella oligopus*, × 25.
6. Do. do. × 25. Dorsal surface.
7. *Holoporella pusilla*, × 25.
8. Do. do. × 85. Operculum.
9. Do. do. × 85. Mandible.
10. *Schizoporella spongites*, × 25. Showing ovicell and vicarious avicularium.
11. Do. do. × 85. Showing the oral denticles from the front.
12. Do. do. × 85. Oral aperture showing the denticles from the interior.
13. Do. do. × 85. Operculum. From Manaar.
14. *Schizoporella unicornis*, × 85. (*a*) Operculum in the oral aperture from lower layer with closure and small tubule; (*b*) do., with large tubule; (*c*) do.; (*d*) do., showing connection from the tubule to the distal wall of the zooecium; (*e*) do., with calcareous covering commencing over the distal part of the operculum.
15. Do do. × 85. Operculum.
16. Do. do. × 25. Zooecium with part of the front wall removed, showing the zooecium of a lower layer in an exactly similar position.
17. Do. do. × 4. Side view of the zoarium, showing the superimposed layers of the zooecia, with some ovicells.
18. *Schizoporella viridis.* Similar multilateral zoarium, showing the irregular position of the layers. From the Red Sea.
19. *Schizoporella poreliformis*, × 25. Showing walls commencing for the next layer, and these walls crossing over the opercula. From Port Elizabeth, S. Africa.
20. Do. do. × 50.
21. Do. do. × 85. Operculum.
22. *Schizoporella unicornis*, × 85. Abnormal double operculum.

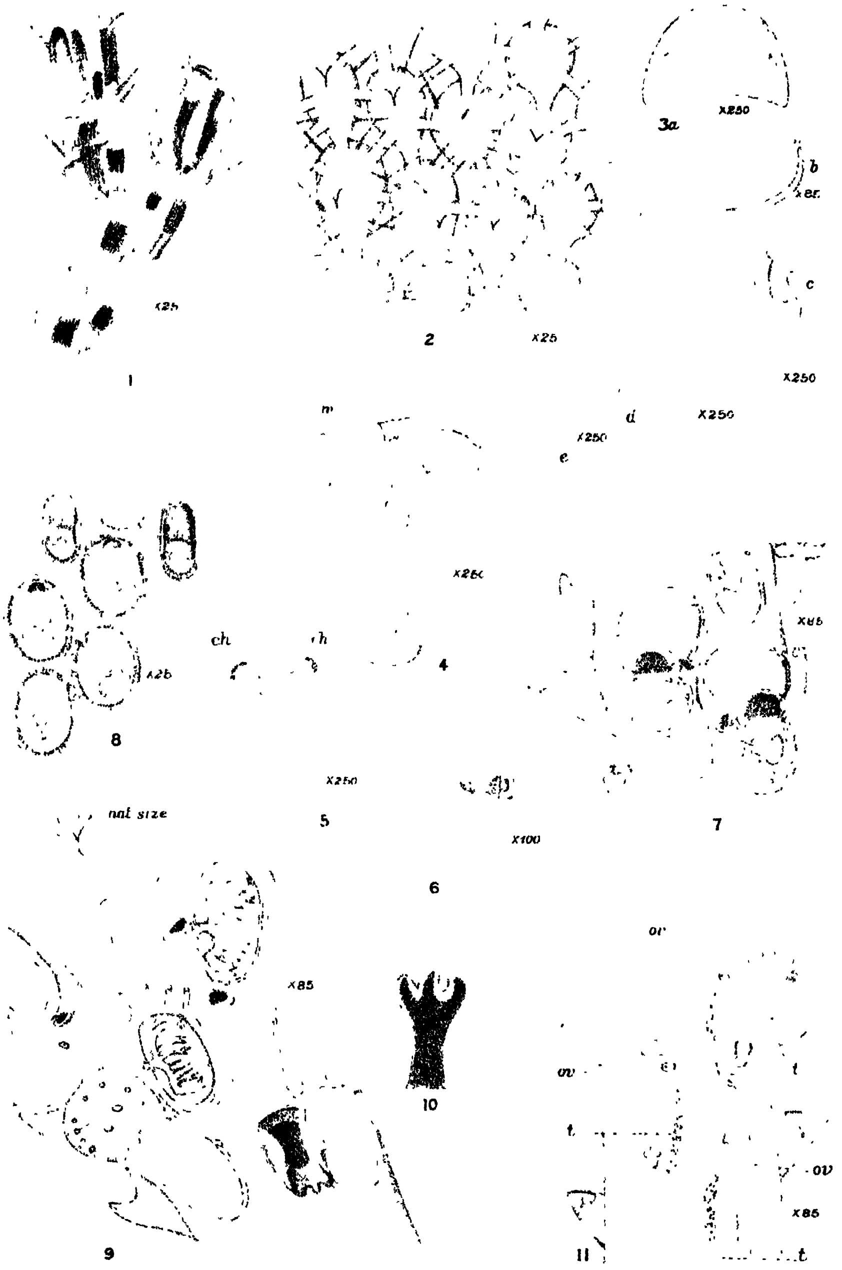
PLATE 3.

Fig. 1. *Crisia tubulosa*, × 25.
2. *Crisia vincentensis*, sp. nov., × 25. Showing long ovicell.
3. Do. do. × 85. Ooeciostome.

XXXIV. Pl. 1.

Waters

JOURN. LINN. SOC ZOOL VOL ~~XXXII Pl 1~~.



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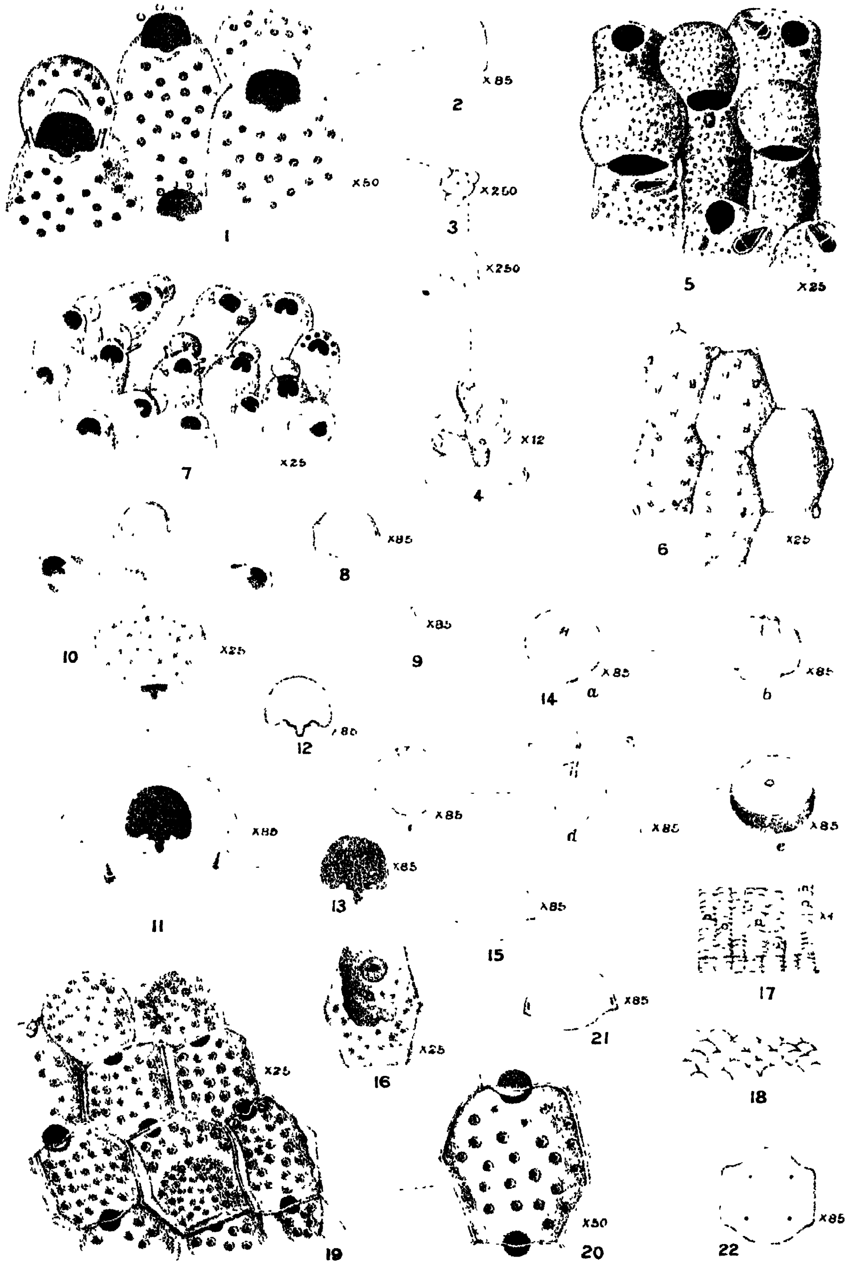

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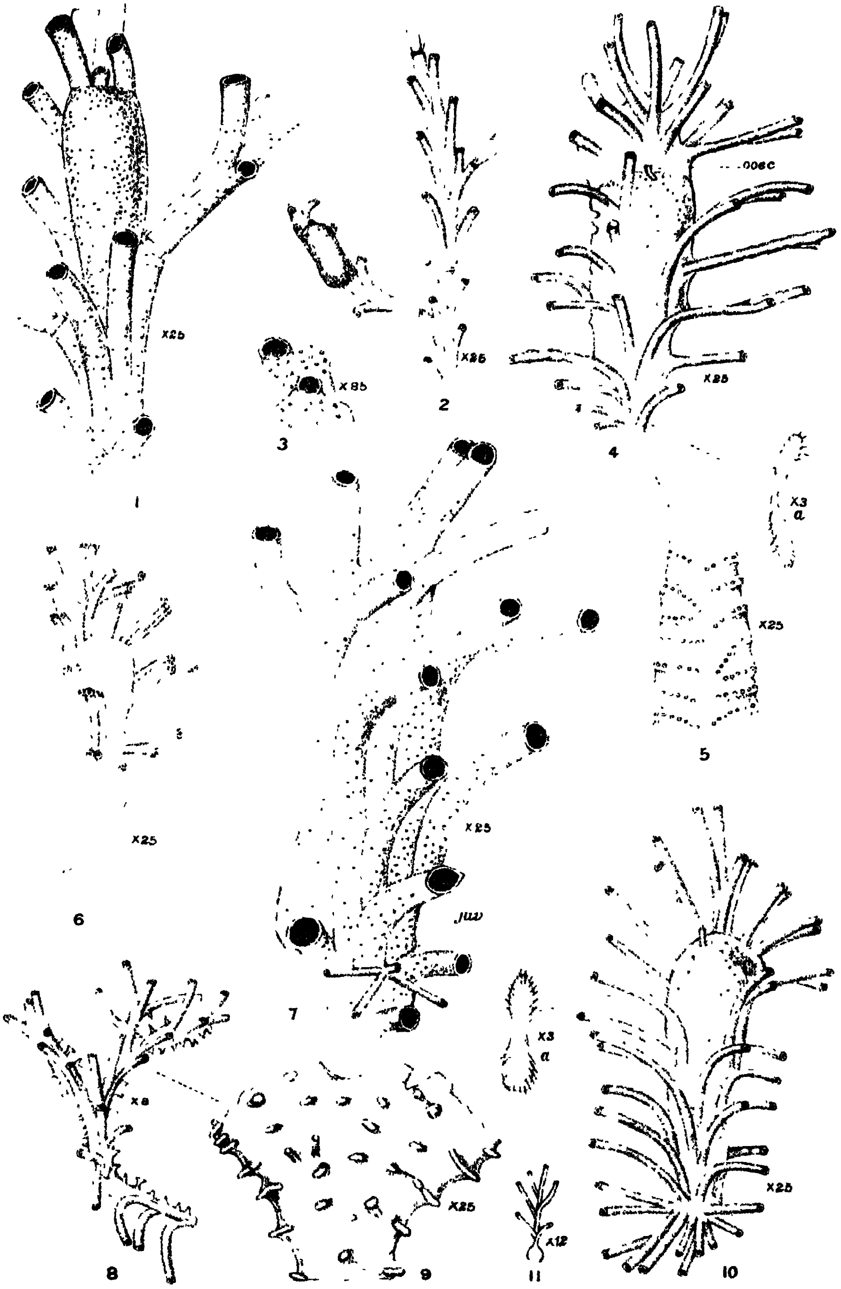

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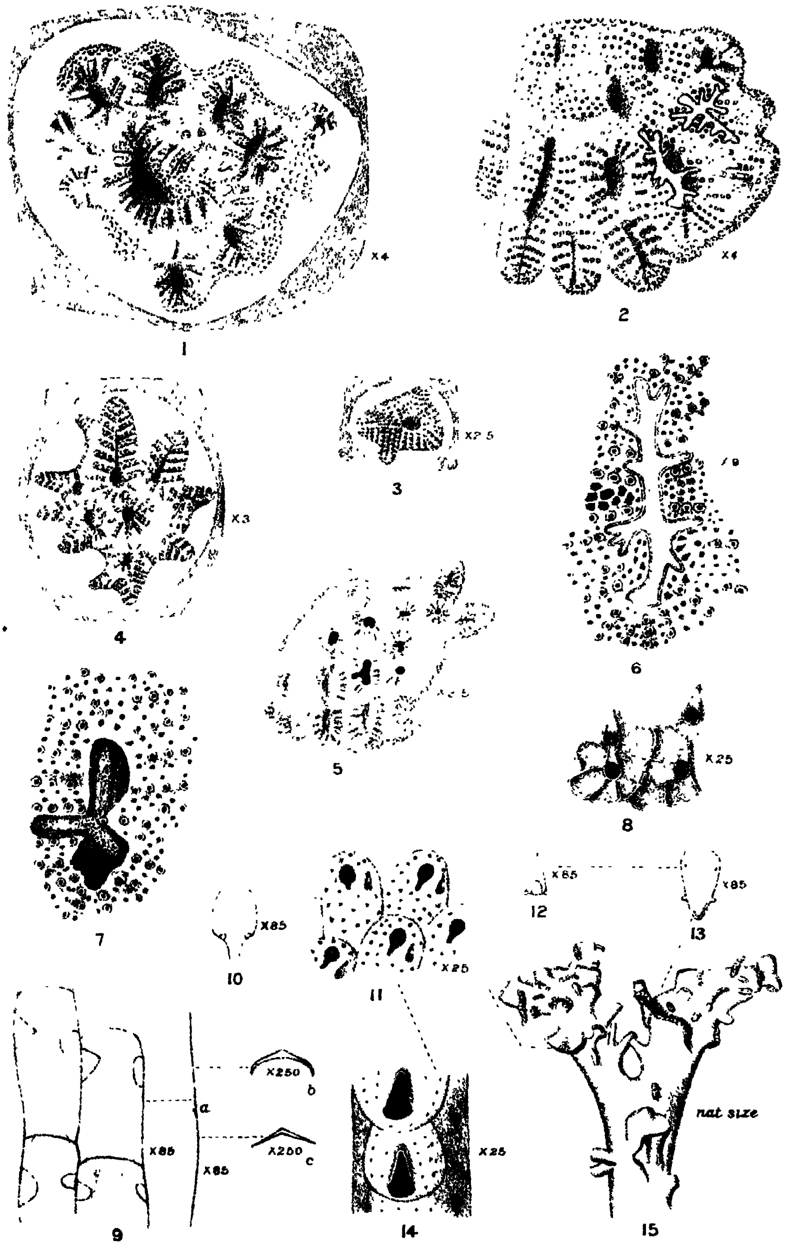

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Fig. 4. *Tubulipora Lamourouxii*, × 25. (*oœc.*) oœciostome. (*a*) × 3.
5. Do. do. × 25. Dorsal surface of fig. 4.
6. Do. do. × 25. The lower part is obscured by *Lithothamnium* growth.
7. *Tubulipora incrassata*, × 25. The magnification of this is the same as of figs. 4, 5, 6, 10. (*Juv.*) is the early growth of *T. Lamourouxii*, Aud., and the difference in the size of the zoœcia of the two species is very marked.
8. *Tubulipora pulchra*, × 8.
9. Do. do. × 25. Dorsal surface.
10. *Tubulipora Lamourouxii*, × 25. (*a*) × 3.
11. Do. do. × 12. Primary and a few zoœcia.

PLATE 4.

Fig. 1. *Lichenopora irregularis*, var. *composita*, var. nov. This form is bi-multiserial, × about 4.
2. *Lichenopora irregularis*, × about 4. This form is uniserial and there are ovicells.
3. Do. do. × 2·5. Small uniserial colony.
4. *Lichenopora irregularis*, var. *composita*, var. nov. Uniserial form showing the elongate extension of the subcolonies.
5. *Lichenopora irregularis*, × 3·5. Ovicells showing several pits.
6. Do. do. Ovicell of fig. 2, more magnified.
7. Do. do. Showing pit at the base of which the upper wall of an ovicell is seen, proving the existence of a subcolony at a lower level.
8. Do. do. × 25. Zoœcia showing the spinous elevation surrounded by cancelli.
9. *Thalamoporella Rozierii*, × 25. Dorsal surface, showing through the walls bundles of spicules near the opesiules. (*a*) Spicule nearly straight, × 85; (*b*) spicule "curve," × 250; (*c*) bent spicule, × 250. It should be noticed that the last two are more magnified than (*a*).
10. *Adeonella contorta*, × 85. Aperture.
11. Do. do. × 25. Zoœcia near growing end.
12. Do. do. × 85. Mandible.
13. Do. do. × 25. Operculum.
14. Do. do. × 25. Lateral view, showing large vicarious avicularia.
15. Do. do. Natural size.

Some Observations on the Feeding-habits of Fish and Birds, with special reference to Warning Coloration and Mimicry. By J. C. Mottram, M.B. (Lond.). (Communicated by Prof. E. B. Poulton, F.R.S., F.L.S.)

(Plate 5.)

[Read 1st March, 1917.]

Material for this paper has been extracted from a journal, wherein are recorded observations of the riverside habits, and especially the feeding-habits, of fish and birds during the years 1909 to 1915 inclusive; they were not collected with any special object in view, and were made in the British Isles and during one season in New Zealand.

The paper is divided into two parts: the first deals with observations which have a bearing on the hypothesis of Warning Coloration; the second with those which appear to throw fresh light on certain aspects of Mimicry.

PART 1.

Feeding-Habits of Salmo fario, *Linn.* (*the Brook Trout*).

The fish is strictly carnivorous. Its food consists of small fish, crustaceans, molluscs, annelids, aquatic and floating insects. Vegetable matter was found on only very few occasions out of five to six hundred autopsies. In New Zealand, on one occasion, the stomach of a fish was filled with *Spirogyra*, Link; subsequently it was proved that the fish took the weed in order at the same time to capture a small Trichopterous larva. The yellow bloom of the furze, *Ulex europæus*, Linn., was also taken on account of a small grub, probably Tineina. In this country pieces of Ribbon-weed, *Potamogeton*, Tourn., are taken in order to obtain *Simulium*, Latr., colonies, either larva or pupa. Sometimes small pieces of wood, of grass stems, and grass and other seeds are found in the alimentary canal; these will be accounted for subsequently.

When the fish are feeding on floating insects conditions are particularly favourable for detailed observation: the insect can be clearly seen and cannot be taken by the fish without a marked disturbance of the surface. The under-water feeding is less easily observed, but examination of stomach and intestinal contents gives reliable information.

The feeding-habits depend to a large extent on the quantity of the food-supply. In waters where food of all kinds is abundant, as in many chalk-streams, the fish, although they have the choice of many kinds of food, always take a mixed diet. It is rare on opening a fish to find the remains of only one kind of food : in one part of the intestine will be found, for instance, snail-shells ; in another fish-bones, and in the stomach insect-remains. The arrangement of the food in the alimentary tract indicates that the fish take their food in batches, the remains of the various foods are more often than not unmixed and occupy different parts of the gut.

Observations in every respect confirm this : a fish picking up snails from the river-bed will never stop to take a floating insect; fish taking floating insects will entirely ignore a shoal of minnows in the neighbourhood; on the other hand, when a fish is taking minnows other foods are neglected. This hunting of one prey at a time is most clearly seen when the fish are taking floating insects. It is the rule in chalk-streams to observe fish taking only one species of insect when there are two or more on the water.

These observations indicate that fish are subject to what may be called a special appetite, as distinguished from a general one. When a fish is observed to be feeding on one insect and neglecting another, it cannot be concluded that there is more than a temporary difference in palatability between these two insects ; it is not unlikely that another fish may be seen feeding on the second insect and neglecting the first. There is some evidence that these individual and temporary preferences depend upon what food the fish has had in the immediate past ; if, for instance, the fish has recently fed upon insects, it will be more likely to take some other food when next hungry. In many rivers during early June *Ephemera danica*, Müll. (the May-fly), hatches out in immense quantities and the fish at once gorge themselves with it ; nevertheless, towards the close of the May-fly season, the fish may often be seen taking other food, whilst *M. danica* is hatching out in abundance the fish may even be seen taking smaller species of the Ephemeridæ or some species of Diptera.

Obs.—15. 6. 1913, R. Kennet, "Found two trout taking 'Olive Dun' (sub-imago of *Baëtis vernus*, Curtis) and neglecting the May flies which were hatching out at the same time. Also saw several dace (*Leuciscus leuciscus*, White) feeding upon 'Reed Smuts' (*Simulium*, Latr.) and neglecting the May fly."

It is well known to fly-fishermen that for some weeks after the May-fly season the fish more or less neglect insect diet: "The May-fly carnival means a long interval, during which the rod may as well be put by, for the glutted fish take a 'cure' of at least three weeks, during which they abstain from insect-food of all descriptions" (from 'Happy Hunting Grounds,' by A. E. Gathorne-Hardy).

In some streams *Brachycentrus subnubilus*, Curtis, (Grannom) hatches out in immense quantities during April, and, in a similar way, the trout quickly satiate themselves with this insect.

A general survey of the feeding-habits of trout, where food is plentiful, brings out three distinct facts: (1) the fish prefer mixed diet; (2) fish feed upon one food at a time; (3) fish have a special appetite as apart from a general appetite.

In waters where food is scarce the fish only grow to a small size. Under these conditions their feeding-habits are entirely different: they take all food that comes within their reach, they are forced by general hunger to eat that which is supplied, they have no opportunity of exhibiting preference. Their method of taking food is shown on examination of their stomach contents; the following are two typical examples:—

"... *Aug.* 21, 1905, R. Lambourne, Great Shelford, part of river where food is scarce, stomach contents were 2 house flies, 2 bluebottles, 1 wasp, numerous reed smuts and other small Diptera, 2 shrimps, 1 snail.

"*Sept.* 10, 1910, Pennel burn, North Wales, stomach contents were 1 grasshopper, 2 wasps, 1 black beetle, several small species of Coleoptera, 1 large Ichneumon fly, 1 daddy-longlegs, 2 hoppers, 6 house flies, 2 caddises, numerous small Diptera, numerous red and black ants male and female, several duns and spinners (sub-imago and imago of Ephemeridæ)."

Had observations been confined to such fish, conclusions would have been drawn that trout appear to have no preference for particular foods.

Evidence that Trout recognize a Difference in Palatability between different Food.

In order to prove that fish do discriminate, a long series of observations must show that, although the fish take both foods, nevertheless, when they have the choice of both, they much more often take one than the other. During May the trout have often choice of two floating insects, the sub-imago of *Baëtis vernus*, Curtis (the "Olive Dun"), and the imago of *Bibio johannis*, Meig. (the "Black Gnat"). It will be seen that some fish are taking both insects, others the *Bibio* only, and others the dun. Each fish thus falls into one of the three classes: by observing a number of fish, distribution of feeding-habit is obtained, as in the following observation:—

May 16, 1910, "Black gnats and olive duns on the water from 10.0 to 11.30 A.M.: of 20 feeding fish, 11 were taking duns only, 7 black gnats only, and 2 were taking both flies."

Similar observations made on many days and on different waters show that the dun, *Baëtis vernus*, is taken more frequently than the gnat, *Bibio johannis*. The number of fish taking both insects was found to depend on the stream on which the observations were made; where the food-supply is scanty the fish most often take both insects, no doubt because their general appetite is very good. Neglecting this class of fish, the following figures were obtained:—Number of fish observed 201, fish taking only duns 149, fish taking only black gnat 52.

Similar observations indicate that the sub-imago of *Baëtis pumilus*, Burm. ("Iron Blue Dun"), is more palatable than *B. binoculatus*, Leach ("Pale Watery Dun"), and that the imago of the smaller Ephemeridæ is more so than *Simulium* ("the Reed Smut").

Even these observations are not quite free from doubt, the relative prevalence of the insects may play a part, or one insect may be more easily captured than another, or more easily seen. Nevertheless, there is stronger evidence that fish do appreciate a difference in palatability. There are two species of the Ephemeridæ, *Heptagenia sulfuria*, Müll. ("Yellow May Dun"), and *Leptophlebia marginata*, Eaton ("Turkey Brown Dun"), which are almost never taken by trout. A "Yellow May Dun" (*sulfuria*) has never been seen to be taken by a trout, though a great number have been observed floating down where fish were feeding. On two occasions considerable hatches of this insect were seen, but the fish left them alone.

Obs.—"*Sept.* 25, 1909, R. Teme, Eardistone, saw a good hatch of the 'yellow May dun' (*H. sulfuria*), many on the water at the same time; this is rarely seen; trout and grayling rising at other flies, but no fish feeding on the 'May dun.'

"*Sept.* 28, another hatch of the 'yellow May dun' (*sulfuria*), fish not taking the insect."

As regards the "turkey brown" (*L. marginata*), I have seen this insect taken on one occasion by two fish, one of which was captured and two recovered from the stomach.

Obs.—"10. 5. 1914, R. Lambourne, Newbury, a hatch of 'turkey browns' (*L marginata*), saw two fish take these insects: killed one and recovered two from the fish's stomach; this is the first time I have seen this insect taken by fish."

It is the experience of anglers that these insects are very rarely taken. These two insects are among the less common species of the Ephemeridæ, and it is possible that their scarcity may be a factor in causing them to be neglected by the fish; on the other hand, fish are often seen feeding on other species even when the hatch is very sparse.

There are two other insects which are almost immune from the attacks of trout, *Gerris thoracica*, Fabr., and *Velia currens*, Latr. ("water-skaters"). In the vast majority of trout-streams these insects abound, but I have never seen one taken by a fish; on two occasions I have recovered single specimens from the stomach. The taking of these insects has been observed by anglers on a few occasions. It is possible the fish neglect them because they are difficult to capture; they are very active, buoyant, and difficult to drown, The only other animal which trout appear to avoid is the tadpole. In lakes and in still pools of most trout-streams tadpoles are found, but I have never seen trout feeding upon them, nor have they been recovered from the alimentary canal. On the river Exe, during 1911, a small pool was observed in which were four trout and tadpoles estimated to the number of two hundred: no diminution of the number was detected during four days. Similar observations were made in a hatch-hole on the river Lambourne at Shelford in 1910, during ten days, with similar result; the possibility of tadpoles dropping down from above was excluded. Nevertheless, on a few occasions anglers have observed trout to be feeding on tadpoles in waters where there was a scarcity of food. The colour of the tadpole deep black, its gregarious habits, its making no attempt at concealment, indicate that the animal is not much open to attack. It is also noteworthy that the vivid yellow of the "yellow May dun" (*H. sulfuria*) makes this insect a conspicuons object on the water; it is certainly more easily seen than any other of the smaller British Ephemeridæ.

These observations indicate that trout do recognise a difference in palatability between different foods; also that the relatively unpalatable foods are occasionally devoured. No small animal which lives either in, or upon the surface of, fresh water has been observed to be entirely immune from the attacks of trout.

The feeding-habits of other fish, in respect of floating insects, is of considerable interest: *Thymallus vulgaris*, Nilss. (the Grayling), takes floating insects as freely as trout; *Leuciscus leuciscus* (the Dace) also feeds freely on floating insects; *Leuciscus cephalus*, Flem. (the Chub), in many streams, only feeds on floating insects during the "grannom" (*Brachycentrus subnubilus*) and "May-fly" seasons, or when an especially large hatch of some other insect occurs, in other streams it rises almost as freely as the dace; *Leuciscus rutilus*, Flem. (the Roach), is very seldom observed to be feeding on floating insects, but during the "May-fly" (*Ephemera danica*) season it not infrequently takes the sub-imago.

As will be seen, a similar sequence is found among the birds: some feed only upon the "May-fly" (*E. danica*), others take other water-insects as well, whilst others again feed freely upon almost every riverside species.

Before considering the significance of these conclusions with regard to warning coloration, some observations on the feeding-habits of birds will be described.

Cypselus apus, Ill. (Swift), *Hirundo rustica*, Linn. (Swallow), *Chelidon urbica*, Boie (Martin), and *Cotile riparia*, Boie (Sand-Martin), feed freely on the sub-imago of the Ephemeridæ, either taking the insects whilst resting on the water or after they have risen into the air. It is rare to see a hatch of these insects without these birds hunting them, so much so that by watching these birds the angler knows when to begin fishing; nevertheless, they occasionally become satiated with these insects. During the close of the "May-fly" (*Ephemera danica*) season it is by no means uncommon to see the swallows hunting over the fields whilst May-flies are hatching-out.

Obs.—"*June* 5, 1913, R. Kennet, Thatcham, whilst a good hatch of *E. danica* was on, swallows were hunting over the meadows to the windward of the river and were therefore not feeding on the 'May fly,' which for several days they have been eagerly devouring."

In contrast to their liking for the Ephemeridæ, they have only on a very few occasions been observed to take the "Black Gnat" (*B. johannis*): there evidently appears to be a distinct difference in palatability between these insects. A difference in the ease with which they may be captured cannot account for the selection, because the birds take other insects whose flight is quite as erratic as that of the "Black Gnat," and also the "Black Gnat" is often over the water in such dense swarms that the birds would have but to fly through them in order to obtain a mouthful, a method of feeding which they often employ for the capture of many small insects which swarm in the air.

Emberiza schœniclus, Linn. (the Reed-Bunting), is very adept at picking the sub-imago of the Ephemeridæ off the water; it in the same way feeds upon *Brachycentrus subnubilus* (the Grannom), and has never been seen taking *B. johannis* (Black Gnat).

Motacilla lugubris, Linn., *M. boarula*, Linn., and *M. rayi*, Bonap. (Wagtails), are commonly seen taking Ephemeridæ; on two occasions, during a double hatch of "Grannom" and "Olive Dun," it was noticed that the birds took the Ephemeridæ by preference, allowing "Grannom," close at hand, to pass untouched whilst flying several yards for a "Dun."

Obs.—"*April* 16, 1910, R. Lambourne, a mixed hatch of 'Grannom' and 'Olive Dun,' 11.0 A.M. to 1.0 P.M., a pair of *M. lugubris* feeding on both flies; when a dun was available it was always taken though 'Grannom' were often closer on the water."

A second observation with *M. rayi*, on the same river, was precisely similar.

A large number of different species of birds collect at the river-side during the "May-fly" season: Fringillidæ (Sparrow, Chaffinch, Greenfinch), *Sturnus vulgaris*, Naum. (Starling), Laridæ (Black-headed Gull and Common Tern), Anatidæ (Ducks), *Muscicapa grisola*, Linn. (Flycatcher), *Anthus pratensis*, Bechst. (Meadow-Pipit), Sylviidæ (Warblers), and other birds which are not, as a rule, observed feeding upon the smaller species of the Ephemeridæ. These observations indicate that the several British species of

Ephemeridæ could be arranged in an order of palatability, both for birds and fish, headed by *Ephemera danica,* as probably the most palatable, and *Heptagenia sulfuria,* as the least.

The habits of the Swift are of particular interest because of its great agility, and the great pace at which it hunts would undoubtedly enable it to take any flying insect—for instance, when feeding on the "May-fly," the impact of bird and fly can be distinctly heard at a distance of ten to fifteen yards. I have seen them take white butterflies on two occasions.

Obs.—"7. 5. 1913, R. Kennet, swifts feeding on 'May fly,' many Pierines crossing the river: the bird caught one with the greatest ease and at once rejected it, the insect fell on the water and was not recovered. 15. 6. 1910, 'swift' took a small garden white at a single swoop, then passed behind a willow tree, out of view."

These observations are recorded because they show that the birds could capture these butterflies did they care to. As a proof that much less agile birds are capable of capturing rapidly flying insects, it may be mentioned that on three occasions Sparrows have been observed amongst new-mown hay successfully chasing *Tryphœna pronuba,* Hübn. (Yellow Under-wing Moth); on two occasions small flocks of these birds were observed feeding in this manner for several hours. Wagtails on several occasions have been observed systematically hunting *Musca domestica,* Linn. (the House-fly), and *Scatophaga stercoraria,* Latr. (the Dung-fly).

The Significance of these Observations with respect to Warning Coloration.

It appears that whether or no an animal will prey upon another depends upon a number of factors, of which the following are the most important:—

(1) The animal's general hunger: a hungry trout will take all that comes within its reach, sometimes even tadpoles; a less hungry fish will only take the more palatable foods, whilst an almost satisfied fish will only take the most palatable.

(2) The animal's special hunger: trout, and less certainly birds, prefer a mixed diet, if an animal has lately become satiated with a particular food, then this food is temporarily lowered in the scale of palatability.

(3) The readiness with which a food can be gathered: animals difficult to capture will be neglected at the expense of those easy to take.

(4) The prevalence of a food-supply: trout, and less certainly birds, appear to concentrate their energies upon hunting one prey at a time; for this reason they will attack a prevalent prey in preference to a scarce one (it has been often observed that birds will feed upon insects when they are unusually abundant and which they have never before been seen to attack).

(5) The animals appreciate a difference in palatability. Possibly there are other factors which control the selection. It is obvious that in order to estimate the palatability of food all these determining factors must be taken into account.

It may here be mentioned that relative palatability may itself depend upon several factors, of which taste and digestibility are not necessarily the most important. The readiness with which the prey can be disposed of is an important one: for instance, when butterflies are attacked by small birds the large expanse of wing protects the small body, the insect is likely to be seized by one or both wings, when the bird shifts its hold in order to dispose of it the wing is momentarily released and the scarcely injured insect escapes, requiring to be recaptured; further, when the insect has been killed, the stiff dry scale-covered wings are difficult to swallow, and are, as a rule, removed before the body is eaten. It would appear that a butterfly is unpalatable in this respect, apart from taste. If warning coloration advertises unpleasant taste there seems no reason why it should not also advertise difficult disposal.

It is also conceivable that warning coloration may similarly advertise difficult capture; on the other hand, conspicuous coloration would give the hunter a good mark to follow. Inconspicuous coloration is of use during motion: a covey of grouse flying over heather can only be followed with the eye for a short distance; should there be a partially white bird among the covey it can be followed over the moors for a mile or so. Entomologists find some inconspicuous butterflies very hard to capture on the wing, not because of rapid flight, but because they are being constantly lost in the background.

The feeding-habits of birds upon butterflies is of special interest because selection by birds has been considered to be a factor in the production of mimicry in these insects. On this account, particular attention has been paid to the feeding of birds upon butterflies. Marshall (1) has collected together the records of the attack of birds upon butterflies up to the year 1909 and given reasons for the paucity of the evidence, which has been considerably increased since then. The evidence at present collected appears to show that—

(1) Birds seldom feed upon butterflies;

(2) They are less often attacked, and are less often found in the alimentary canal of birds, than are many other insects.

(Further evidence may, however, negative both these statements. Whenever accurate field-observations are made these instances of birds feeding upon butterflies are by no means infrequently recorded. Swynnerton has shewn that these insects are so broken up in the alimentary tract of birds that a careful microscopical examination is required for their recognition.)

It has therefore been concluded that on broad lines butterflies are less palatable than many other insects, and that their diurnal habits, relatively slow flight, and conspicuousness may be looked upon as warning characters.

The wings of butterflies, apart from pattern and coloration, are conspicuous on account of their large size (size is a very powerful factor as regards visibility), and also on account of their opacity (transparent wings are a great aid to concealment). Although butterflies as a whole may be less palatable than many other insects, it does not follow that among them there may not be difference in palatability, just as there is in the Ephemeroptera towards fish and birds; and just as butterflies may as a whole exhibit conspicuous (warning) characters so, among them, according to their palatability, some may exhibit more conspicuous characters than others. If animals can be arrranged in an order of palatability, and if warning coloration and protective resemblance are the result of selection by enemies, then animals liable to attack should also form a series presenting all grades, from a most pronounced conspicuous coloration to a great protective resemblance, the intermediate forms showing something of both. Some evidence has been brought forward that this occurs in the Ephemeridæ. In a previous paper (5), the factors for conspicuous pattern were ascertained by experiment with artificial pattern, and it was shown that among Indian Lepidoptera some of the insects present all the factors for conspicuousness; others, some only; whilst others, only a few. Swynnerton (2) has shown that animals, which form the food-supply of any species, can be arranged in order from the most palatable to the least palatable; and opinion is expressed that animals bear some distinctive mark whereby a preyer can recognise and distinguish the relatively unpalatable from the relatively palatable. The "distinctive" coloration need not necessarily be very conspicuous. Unpalatable animals can afford to carry a conspicuous mark, but the relatively palatable can only carry one, which is to a small extent conspicuous, or one which is only displayed when concealment has failed.

This conception is similar to the author's, but is better in that, by replacing the term "warning coloration," it brings into line those slightly conspicuous characters which cannot be called "warning" characters. The conception presumes that preying animals have a memorising power of considerable magnitude, but this presumption does not appear to be always necessary: for instance, a very strong family likeness runs through long series of protected species of butterflies. Swynnerton says of this, "This can be accounted for by the advantage of maintained notoriety." If, however, a number of different butterflies present very conspicuous characters, they must be very similar in appearance, because the majority of the factors for conspicuousness must be present in each. Poulton (3), so long ago as 1887, observed that certain colours and patterns associated with unpalatability, do constantly recur among insects, both in the larva and adult states. It follows that in this case unpalatability might be associated in the preyer's mind, not with a particular form, colour, pattern, or other character, but with conspicuousness. If a bird be given a conspicuous insect which it has never before seen it will be shy in attack; whereas when the insect is inconspicuous the bird's attack will be bolder. Variations in edibility may be associated in the preyer's mind with degrees of conspicuousness rather than with distinctive markings: many distinctive marks appear to be related to concealment rather than the reverse; nevertheless, as a working hypothesis, Swynnerton's conception may prove to be of considerable value.

(3) Birds have been observed sometimes to exercise no choice with respect to butterflies on which they are feeding. As has been already seen, the conclusion that they do not recognise a difference in palatability cannot be drawn.

(4) Birds have been sometimes observed feeding upon presumably protected butterflies, Euplœines and Danaines. Conclusions cannot be drawn that they are not relatively unpalatable; trout will sometimes feed upon tadpoles.

(5) Birds have on a few occasions (4) been observed to feed upon some butterflies, whilst neglecting others. This might be the result of a temporary special appetite of the bird, the difference in the ease of capture of the insects, or by a difference in the relative prevalence of the insects. Only after exclusion of these and other factors can it be concluded to be due to a difference in palatability.

PART 2.

Observations which show that Salmo fario *mistakes other things for Floating Insects, and fails to distinguish Artificial Flies from Natural Ones.*

As already mentioned, examination of the alimentary contents often reveals the presence of small pieces of wood, stick, grass-stem, and seeds, more especially grass-seeds. If a trout, which is feeding on floating insects, be observed over a long period, it will be seen often closely to examine many such small floating things; the majority of these the fish will neglect, a few will be taken into the mouth to be at once rejected, a small proportion is swallowed. There can be no doubt that the fish mistakes these things for the insect on which the fish is feeding at the time, and it may be concluded that its vision is not very acute. If the fish is feeding on one particular insect, as is most often the case in chalk-streams, mistakes are much more seldom made than when the fish is feeding on any floating insect which the stream may bring down.

The following are samples of the observations :—

Obs.—" *March* 30, 1911, lake Okeraka, New Zealand, stomach contents of trout were four grasshoppers, two cicadas, and three short pieces of stick of about the same length and thickness as the grasshoppers.

" *July* 21, 1911, R. Kennet, Newbury, stomach contents were many ' Pale Watery Duns ' (*Baëtis binoculatus*) and three grass seeds similar in size to the bodies of the insects.

" *July* 5, 1909, R. Lambourne, Shefford, watched a fish for half an hour taking ' blue-winged olives ' (*Ephemerella ignita*, Poda) and ' Reed Smuts ' (*Simulium*), fish always examined any small floating object which at all resembled the insects ; on more than a dozen occasions such things were mouthed, and twice, evidently swallowed."

More certain evidence that trout are easily deluded is provided by the fact that the dry-fly fisherman is able to kill fish with crude floating imitations of the natural insects made of fur and feather. Dry-fly fishing consists of floating over the fish and making to rest on the surface of the water, a dry artificial insect in imitation of the natural one on which the fish has been observed to be feeding. In streams which are little fished the fish are easily deluded ; but, in heavily fished waters, they become educated and are able, on close inspection of the insect, to detect the counterfeit. This education is the result of the fish having been either caught and returned, or hooked and lost on many occasions. The Plate (Pl. 5) shows a series of artificial insects photographed against a high light, as the fish see them. It illustrates the roughness of their resemblance to the natural insects. The artificial insect may be looked upon as an unpalatable insect mimicking a palatable one, and the facts show that a crude mimicry is of considerable power for delusion.

Observations which indicate that Birds mistake inanimate things for Flying Insects, and the Angler's Fly floating on the water for Insects similarly situated.

If *Muscicapa grisola* (spotted flycatcher) or any of the species of swallows or martins be watched, over a long period of time, whilst they are feeding on flying insects, it will be noticed that not infrequently the birds start out from where they are resting, or alter their line of flight, in order to capture small pieces of feather, seed-plumes, leaf-scales, chaff, or other light bodies floating in the air, which they obviously mistake for flying insects ; as a rule, closer inspection shows them their mistake. Sometimes the object is taken in the bill and subsequently dropped ; or very occasionally it appears to be swallowed. The following are details of some of the observations, given to show that the above statement is not open to doubt.

Obs.—"3. 6. 1913, watched a spotted flycatcher feeding upon small flying insects, chiefly gnats, observations extending over half an hour, bird seen to set out after small pieces of feather, chaff, &c. on three occasions, and a fourth time the object was taken in the bill.

"13. 5. 1914, swallows feeding upon 'olive duns,' bird took small piece of feather which was not seen to be discarded.

"18. 4. 1910, wagtails feeding upon 'Grannom,' on several occasions bird made for small floating objects resembling the insect, and twice picked these off the surface of the water, then dropped them."

Whilst making such observations, it was noted that the birds often flew long distances after passing insects, as much as twenty yards, and that many of the mistakes were then made.

The dry-fly fisherman's evidence that birds are easily deluded, is very clear. Swallows, martins, and swifts very commonly pick the artificial insect off the water, when an imitation of one of the Ephemera is being used. Two typical experiences are given :—

Obs—"5. 7. 1909, R. Lambourne, Great Shelford, 3.0 to 4.0 P.M., hatch of 'Blue-winged Olives' (*Ephemerella ignita*), swallows picking insects off the water as well as taking them in the air, my artificial 'Blue-winged Olive' was repeatedly picked off the water and carried for a yard or two in the air, by both swallows and martins : so persistent were the birds that they interfered with the fishing.

"20. 4. 1913, hatch of 'Grannom,' 11.0 to 12.30, black-headed bunting picking insects off the water, on two occasions bird mistook my artificial insect."

Similar mistakes have been personally witnessed in the case of the following birds : *Motacilla rayi, M. boarula, Sterna* (a tern in New Zealand), *Anthus pratensis, Acrocephalus schœnobænus*, Newton, *Caprimulgus europæus,* Linn., *Anser* (domestic duck), *Podiceps fluviatilis,* Degl. & Gerbe, and species of Bat (undetermined).

It is clear therefore that birds, like trout, frequently mistake crude imitations for living insects.

The Importance of these Observations with respect to certain Aspects of Mimicry.

It has been shown that a crude resemblance suffices to delude both birds and trout. It would appear therefore highly probable that if one insect only slightly resembled another, which the bird was avoiding, then the mimicking insect would, to some extent, be also avoided. The fact that birds have been observed to begin their attack from considerable distances would help to give value to a crude resemblance ; because at such distance all details of pattern and coloration (especially during motion) cannot be seen.

These considerations are of some importance, because it is difficult to conceive how mimicry can have had a beginning, except by a variation of considerable magnitude; further, it has been thought that birds would be able to see through a disguise, unless it were good. However, the observations which have been recorded indicate that both birds and fish are easily deceived, and that a crude resemblance would be likely to give a mimicking insect some protection, and especially because birds often begin their attack from such a distance that many details of pattern and coloration are invisible. On the one hand, a bird may allow to pass at twenty feet a mimic which is only a poor imitation of a protected species; on the other hand, at two feet, a good imitation may be necessary for immunity from attack. It would follow that, although a poor imitation may gain some protection, a good mimic would gain more; so that from a rough resemblance, a good resemblance could conceivably be built up by the agency of selection by birds. There is ample evidence that butterflies, as a whole, are less palatable to birds than many other groups of insects. An examination of their form, pattern, coloration, and habits shows that they exhibit several characters which must render them, relatively to other insects, conspicuous in Nature. Nevertheless, if butterflies, as a whole, be considered to present some warning characters, it obviously does not follow that, within the group, there may not be degrees of palatability associated with variations in the amount of warning coloration, and that therefore there may not be also within the group mimicry.

SUMMARY.

Attention is especially directed to two aspects of the relations between preyer and preyed upon.

First, that there are many factors which determine whether or not, at any particular time, one animal will prey upon another, of which relative palatability is only one. In order, therefore, to demonstrate a difference in palatability between various foods, all these determining factors must be taken into account.

Second, that observations indicate that both birds and fish are deluded by rough resemblances to the insects upon which they are at the time feeding.

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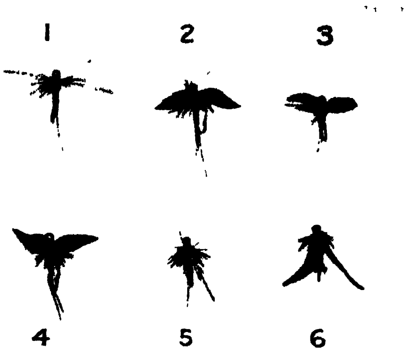
PLATE 5.

ARTIFICIAL INSECTS. (Halford's patterns.)

The Explanation is printed at the foot
of the Plate.



ARTIFICIAL INSECTS (HALFORD'S PATTERNS)

FIG. 1. Male imago of *Baëtis pumilus*, Burm. ("Iron Blue Spinner").
" 2. Female sub-imago of *B. pumilus* ("Iron Blue Dun").
" 3. Female sub-imago of *B. binoculatus*, Leach ("Pale Watery Dun").
" 4. Female sub-imago of *B. vernus*, Curtis ("Olive Dun").
" 5. Male *Bibio johannis*, Meig. ("Black Gnat").
" 6. Female *Brachycentrus subnubilus*, Curtis, carrying green egg-sac ("Grannom").

Description of *Paracubaris spinosus*, a new Genus and Species of Terrestrial Isopoda from British Guiana. By WALTER E. COLLINGE, D.Sc., F.L.S., etc., Carnegie Fellow, and Research Fellow of the University of St. Andrews.

(PLATE 6.)

[Read 3rd May, 1917.]

IN June last I received from Mr. G. E. Bodkin, the Government Economic Biologist at Georgetown, Demerara, British Guiana, two specimens of Terrestrial Isopods collected from decaying wood, Mazakuvi River, British Guiana, a very slight examination of which was sufficient to indicate that they differed in a number of important structural characters from the genus *Cubaris*, Brandt, to which they bore a superficial resemblance.

A closer examination shows that whilst belonging to the Cubaridæ, they are quite distinct from the genus *Cubaris* or any of its allies, and necessitate the erection of a new genus, which I am here describing under the name of *Paracubaris*.

PARACUBARIS, gen. nov.

Body oblong-oval, segments strongly convex, whole of dorsal surface covered with short, blunt spines. Cephalon short and wide, cephalic lobes absent, epistome dorsally sloping and keeled in the median line. Eyes compound, situated dorso-laterally. Antennæ with 2-jointed flagellum and elongated terminal style. Inner lobe of maxillipede without spines, terminating in a setaceous pad. Pleural plates of mesosomatic segments slightly excavate and terminally the 2nd to 5th bluntly pointed. Only the first segment exhibits a slight thickening on the inner lateral margin. Uropoda extending beyond the telson; basal plate thick and flattened, exopodite articulating with the posterior inner border, short and broad and extending beyond the basal plate, endopodite long, both exo- and endopodite have a short terminal style. Telson triangular, terminally bluntly rounded, proximally wider than the length.

Paracubaris differs from the genus *Cubaris*, Brandt, in the form of the cephalon, antennæ, maxillipedes, and the first mesosomatic segment. Unlike any member of the latter genus the uropoda extend beyond the telson and in the form of both of these structures there are well-marked differences.

In the position of insertion of the exopodite *Paracubaris* shows a relationship with *Pseudarmadillo*, Saussure *, *Sphæroniscus*, Gerstaecker †, and

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* Rev. et Mag. Zool. (s. 2), vol. ix. (1857) p. 308, and Mém. Soc. Phys. et d'Hist. Nat. Genève, vol. xiv. (1858) p. 488, figs. 43, 43 *a*.

† Ent. Zeit. 1854, p. 314.

Haplarmadillo, Dollfus [*], but differs from the first-mentioned genus in the form of the cephalon and first mesosomatic segment, from the second in the two-jointed flagellum of the antennæ and in only the first two metasomatic appendages having pseudo-tracheæ, whereas in *Sphæroniscus* they are present in all the five appendages. In *Haplarmadillo* the flagellum of the antennæ has but a single joint and the eyes are simple. The new genus is more closely related to the genus *Minca*, Pearse [†], recently described from Colombia, which possesses a two-jointed flagellum, a triangular-shaped telson, and broad flat uropoda, which extend beyond the metasome.

PARACUBARIS SPINOSUS, sp. nov. (Plate 6.)

Body oblong-oval, segments strongly convex, dorsal surface covered with short blunt spines, finely granulose. Cephalon (figs. 1 & 2) short and wide, with well-marked anterior and posterior margins; cephalic lobes absent; epistome dorsally sloping from the anterior margin of the cephalon, keeled in the median line, concave laterally. Eyes compound, situated dorso-laterally. Antennulæ (fig. 3) 3-jointed, distal joint with few stout spines laterally and fine terminal style. Antennæ (figs. 4 & 5) of medium length, 1st joint short, 2nd grooved on the outer side, 5th joint elongated; flagellum 2-jointed, distal joint the smaller, with elongated terminal style. First maxillæ (fig. 6), outer lobe terminating in four outer, stout, curved spines and eight smaller inner ones; inner lobe terminally rounded, with two spines covered with fine short setæ. Maxillipedes (fig. 7), the terminal joint of the outer palp is multispinous, two multispinous processes arise from the middle joint, and there is a single large spine on the inner border of the first joint; the inner lobe is without teeth or spines, but has a well-marked setaceous pad terminally. The segments of the mesosome are strongly convex, pleural plates all slightly excavate, those of 2nd to 5th segments terminally bluntly pointed, remainder truncate, posterior angles undeveloped. The first segment has a slight fold on the outer margin, which ventrally appears as a thickening (figs. 8 & 9). Thoracic appendages normal, enlarging slightly posteriorly. Uropeda (fig. 10) extending beyond the telson; basal plate thick and flattened, with slightly raised diagonal crest, exopodite short and broad, articulating with posterior inner border and extending beyond the basal plate a little, endopodite long, both spinous and with small terminal styles. Telson (fig. 11) triangular, terminally bluntly pointed, proximally wider than the length. Length 20·5 mm. Colour (in alcohol) greenish-brown with lateral areas on the mesosome of brown and white mottling.

Habitat. In decaying wood, Mazakuvi River, British Guiana, May 1916 (*G. E. Bodkin*).

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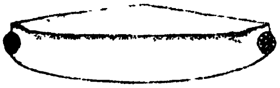
[*] Proc. Zool. Soc. Lond. 1896, p. 399.

[†] Proc. U.S. Nat. Mus. vol. xlix. (1915) p. 544, fig. 6.



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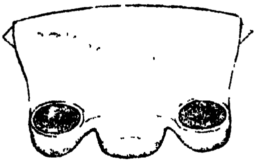

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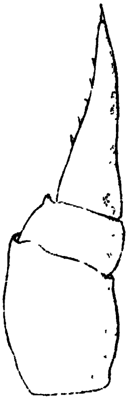

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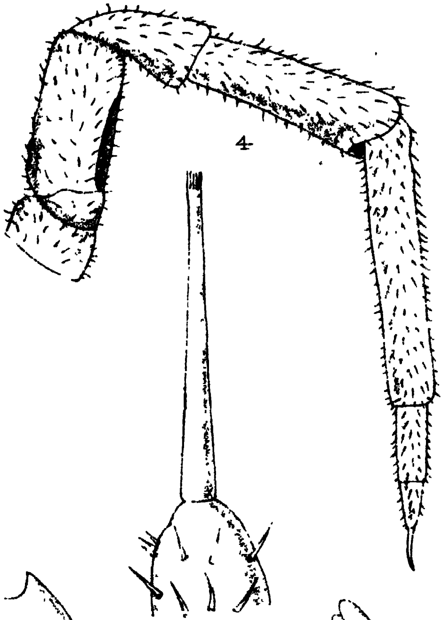

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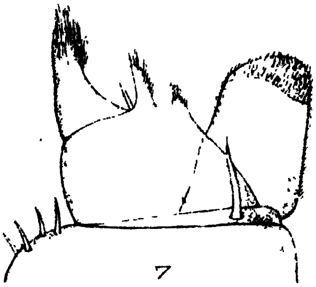

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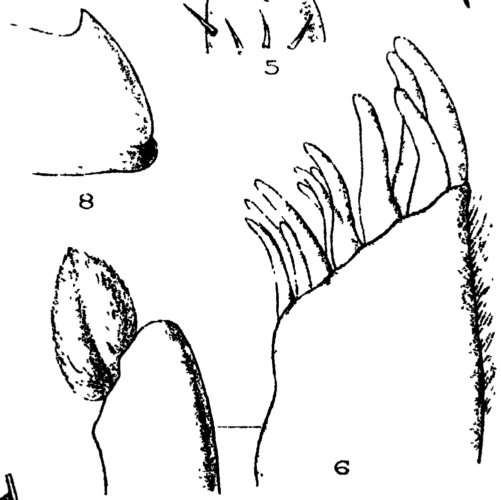

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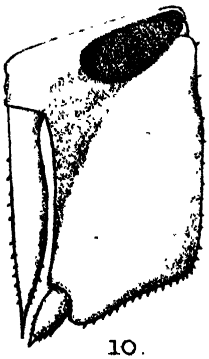

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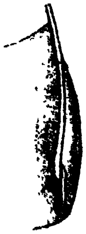

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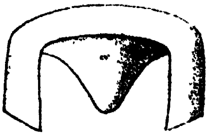

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S.R.K. del. ad. nat. C Hodges & Son. lith & imp.

PARACUBARIS SPINOSUS.

Type. In collection of W. E. C.

Paracubaris spinosus is of special interest in that it represents a type of Cubaridæ only known as yet from the Western Hemisphere. The short wide cephalon is very different from the form seen in *Cubaris*, Brandt, and the sloping epistome, present in some species of this last-mentioned genus, is also present here, a fact which would seem to considerably weaken the importance attached to this particular character by Budde-Lund, who regarded it as of generic importance.

The antennæ are distinctly Cubarid, and differ from those in *Cubaris* only by the absence of the grooves on the outer side, and in that the distal joint of the flagellum is shorter than the proximal one.

The maxillæ offer no characters of importance, but the inner lobe of the maxillipede is curious in possessing a setaceous pad terminally in place of the usual tooth-like spines. This feature occurs in many genera of Terrestrial Oniscoida, but not, so far as I am aware, in any belonging to the Cubaridæ.

The pleural plates of only the second mesosomatic segment exhibit any thickening of the coxopodite, and these are of a very simple nature (figs. 8 & 9).

The uropoda are very distinct from those of any other genus of the family, being thick and flattened with the exopodite inserted on the posterior inner border of the basal plate. They extend beyond the telson. On the outer lateral and posterior border of the basal plate are a number of strong short spines, and a few similar ones are present on the exo- and endopodites.

As in *Minca*, Pearse, the telson is triangular and does not extend to the end of the metasomatic segments.

EXPLANATION OF PLATE 6.

***Paracubaris spinosus*, gen. et sp. nov.**

Fig. 1. Dorsal view of the cephalon. × 8.
2. Anterior view of the cephalon. × 8.
3. Dorsal view of the right antennule. × 70.
4. Dorsal view of the right antenna. × 14.
5. Terminal style of the antenna. × 110.
6. Terminal portions of the inner and outer lobes of the right 1st maxilla. × 70.
7. Terminal portion of the left maxillipede. × 48.
8. Ventral view of the outer margin of the 2nd mesosomatic segment. × 6.
9. Terminal margin of the same. × 8.
10. Dorsal view of the right uropod. × 14.
11. Telson and last metasomatic segment. × 6.

The author desires to thank the Carnegie Trust for the Universities of Scotland for a grant to defray artist's charges.

On the Oral Appendages of certain Species of Marine Isopoda. By WALTER E. COLLINGE, D.Sc., F.L.S., Carnegie Fellow, and Research Fellow of the University of St. Andrews, the Gatty Marine Laboratory, St. Andrews.

(PLATES 7–9.)

[Read 3rd May, 1917.]

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I. INTRODUCTION.

THERE are few groups of animals that present greater difficulties in connection with their classification than the Order Isopoda.

Much of the work of the earlier carcinologists has, in the light of recent research, proved to be very imperfect, and many of the genera and species classified as related to one another have been shown to be widely separated. Further, structural characters that hold good for certain divisions of the Isopoda are quite unsatisfactory for others. This is particularly well illustrated in the oral appendages. I have elsewhere (7) expressed the view, and shown, that in the suborder Oniscoidea, Sars, these appendages "are liable to a large amount of variation in individual species, and are therefore characters of only minor importance as compared with the form of the head, antennæ, telson, uropoda, mesosomatic segments, and thoracic appendages," and I believe that further investigations will serve to corroborate and strengthen this view so far as the strictly terrestrial forms are concerned, where considerable modification and degeneration have taken place.

On the other hand, in certain suborders of marine Isopoda these same appendages would seem to be fairly constant in form, and to offer excellent data for the characterization of both genera and species (8–12).

Recent work on the suborder known as Valvifera shows that the form of at least two of the four oral appendages affords most valuable aid in the discrimination of both genera and species, viz., the first maxillæ and the maxillipedes. In this connection it is interesting to note, that in the members of the family Idoteidæ they differ very little in the immature stages from that obtaining in the adult; they are thus frequently of great service for purposes of identification. A further interesting point relative to the two pairs of maxillæ, and in a lesser degree the maxillipedes also, is the frequency with which the "casts" of these appendages remain attached to the newly formed ones, and they often serve a useful purpose in aiding in the elucidation of minute structural details, as, being free from all muscular attachments and almost void of pigment, they can easily and quickly be made transparent.

It is therefore much to be regretted that many authors have given no description or figures of the form and structure of these appendages in quite a large number of species.

In the present communication I have endeavoured to remedy this to some extent by describing and figuring the first maxilla (occasionally the second) and the maxillipede in 24 species referable to 9 genera of the family Idoteidæ, in none of which, so far as I am aware, have they both been described, and also to correct some errors in a few of the figures and descriptions where the maxillipede only has been partly described and incorrectly figured.

I have much pleasure in here expressing my thanks to the authorities of the U.S. National Museum, Washington, for specimens of many of the species examined; to Professor D'Arcy W. Thompson for examples of *Mesidotea sabini* (Kröyer); to Professor Chas. Chilton for various New Zealand species; to Mr. Keppel H. Barnard for many South African species; and to Mr. Walter H. Baker for South Australian species.

Under the different species the more important references have been given, but no attempt has been made to give the complete list of synonyms or references.

II. METHOD OF PREPARATION.

Most of the errors in previously published figures and descriptions of the oral appendages of the Idoteidæ are due to the fact that the different segments, joints, spines, etc. are not always shown, and this has no doubt partly arisen owing to the appendages having been imperfectly prepared for microscopical examination.

The old method of boiling or even soaking in a solution of caustic soda is unsatisfactory, as frequently the different parts become separated from one another and also become altered in form to a greater or lesser degree.

After considerable experimentation, I think I have at last arrived at a method that is thoroughly satisfactory. So far as I am aware, the details have not previously been published; it therefore seems desirable to describe the method in detail.

The original idea of treating chitin as described below is Professor J. C. Irvine's, who adopted it in a research on the chemical nature of chitin derived from different sources [*]. He has very kindly given me the essential details of the process, and with these I have made numerous experiments and modifications, ultimately evolving the following process for clearing and staining small chitinous objects, such as the appendages and other parts of the exoskeleton of crustacea.

All the material dealt with had previously been preserved in alcohol. Upon removing the appendage or particular part to be studied, it was placed in a small quantity of a 15 °/₀ solution of HCl, and there allowed to remain for a period varying from twenty minutes to three hours, according to the size and thickness of the object. The receptacles used for containing the specimens and fluids were small flat glass dishes 39 × 39 × 9 mm. with a circular concavity 5 mm. in depth, and covered with a square of glass. Upon removing the specimen from the HCl it was well washed in distilled water and then transferred to a 5 °/₀ solution of caustic soda, in which it was allowed to remain for one to three hours, and then placed in a 4 °/₀ solution of sodium permanganate for a period varying from thirty minutes to two hours. Finally, it was again placed in a 15 °/₀ solution of HCl for ten to sixty minutes. After further careful washing the specimen was dehydrated and then stained with Meyer's alcoholic carmine.

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[*] Trans. Chem. Soc. Lond. vol. xcv. (1909) pp. 564–570.

Most of the material was examined in xylol, some was mounted in Canada balsam (xylol) and some in Farrant's solution, but none of the specimens were improved by the use of either of these media—the former proved the better of the two.

I should strongly recommend anyone trying this method to first experiment with some material of no value, as it is only by experience that one comes to appreciate just the right time to remove the specimens from one solution to another. If removed too soon little change has taken place; on the other hand, a very short excess period is sufficient to ruin the object.

If the above-mentioned small flat glass dishes are used the specimens can be examined from time to time under a low-power of the microscope and the progress and changes noted.

The value of this method of treating small, jointed chitinous objects lies in the fact that, if carefully handled, little or no displacement of the different parts takes place; further, the objects are rendered perfectly transparent, all cellular tissue and pigment being removed, and a uniform stain is taken up by the margins of all joints, segments, spines, etc. Setæ which appeared to arise as stiff spines from the surface of a body can, by this method of preparation, be seen to pass beneath the surface at their proximal ends and to be lodged in tiny pits or articular cups, whilst others that appeared to be perfectly smooth are found to carry smaller spines, teeth, etc.

It is with considerable pleasure that I here acknowledge my indebtedness to Professor Irvine for the basis of this method, and for the, at all times, kindly criticism and advice he has given.

III. THE ORAL APPENDAGES OF THE FAMILY IDOTEIDÆ.

The two principal appendages that have been employed in the classification of the members of the suborder Valvifera are the first maxillæ and the maxillipedes, and I propose to offer some few remarks upon these as presented in the family Idoteidæ.

The First Maxillæ.—Each maxilla consists of a pair of elongated chitinous bodies—the inner and outer lobes—connected by a small basal segment. The outer lobe is slightly convex on the ventral side and almost flat dorsally, usually the anterior half, or even two-thirds, is wider than the posterior portion. Setules, small plain spines, set in cup-shaped articular cavities may or may not be present on the anterior part of the ventral surface. Distally there are a variable number of curved spines. In many species these are divided into two distinct sets, viz., an outer series of stout, curved, bluntly pointed ones, and an inner series of thinner, more slender, usually sharply pointed ones, which have one or more rows of teeth on their sides, which vary considerably in number and size. The two series are frequently separated by a long, slender, sharply pointed spine. There are often a series of setæ on the anterior outer (and sometimes inner) border..

The inner lobe shows considerable variation in the different genera. It consists of an elongated, narrow, posterior portion, which widens anteriorly into an oval or more or less triangular, flattened plate, with two to four setaceous spines at the distal extremity, in addition to which, one or more setules may be present. In a few cases the number of setaceous spines may be greater on the appendage of one side than on that of the other.

The Maxillipedes.—Each maxillipede consists of a divided coxopodite, a basipodite with a short inner lobe on the inner side, and an outer lobe or palp (endopodite) articulating with the basal segment on the outer side. On the outer side posteriorly there is a wide, more or less oval, plate, the epipodite. The divisions of the coxopodite lie respectively posterior to the epipodite and basipodite. The inner lobe of the basipodite is generally fringed distally with a number of setose and plain spines, and on its inner side and about its middle is a curved process which serves to hook together the appendages of the two sides. Occasionally there are two or more of these processes.

The outer lobe or palp is composed of a varying number of joints, but the first or "collar"-joint, a short one immediately anterior to the basipodite, is, I believe, present in most genera. It would seem to be absent according to Miss Richardson (21) in the genus *Chiriscus*, for no such joint is shown in the figure of the maxillipede of *Chiriscus australis*, Richardson.

In *Edotia*, Guérin-Mén., *Synidotea*, Harger, *Chiridotea*, Harger, and *Macrochiridothea*, Ohlin, there are three joints in the palp of the maxillipede; in *Idotea*, Fabricius, *Erichsonella*, Benedict, *Colidotea*, Richardson, *Eusymmerus*, Richardson, *Synisoma*, Collinge, and *Euidotea*, Collinge, four joints are present; whilst in *Crabyzos*, Spence Bate, *Mesidotea*, Richardson, *Pentidotea*, Richardson, *Pentias*, Richardson, *Zenobiana*, Stebbing, *Glyptidotea*, Stebbing, *Paridotea*, Stebbing, *Cleantiella*, Richardson, and *Engidotea*, Barnard, there are five divisions in the palp.

It is very doubtful whether the structure of these parts indicates in any way the phylogeny of these crustacea. In any attempt therefore to estimate the value of these appendages for purposes of classification due consideration should be paid to the segmentation of the metasome, and also to any evidences of degeneration or special modification.

It may be interesting to roughly classify the known genera according to the segmentation of the metasome and the number of joints of the palp of the maxillipede.

The primitive Idoteidæ, in all probability, possessed a metasome composed of five distinct segments and a palp on the maxillipedes having five joints. Such a type is probably represented by *Proidotea*, Racovitza and Sev., although the maxillipedes have not been seen of this extinct genus. *Mesidotea*, Richardson, would follow, and then *Chiridotea*, Harger, where a segment of the metasome has become fused, but a suture remains indicating it. Although undoubtedly related to the former genus, the palp of the maxillipede is composed of only three joints. The position of *Macrochiridothea*, Ohlin, and *Chiriscus*, Richardson, is somewhat doubtful.

In a second group we have *Pentidotea*, *Zenobiana*, *Glyptidotea*, *Paridotea*, *Pentias*, *Crabyzos*, *Cleantiella*, and *Engidotea*, in all of which genera the palp of the maxillipede possesses five joints. In *Zenobiana* there is often a metasome composed of five segments, and in all the remaining genera there are indications of four segments.

In a third group must be placed *Idotea*, *Colidotea*, *Eusymmerus*, *Erichsonella*, *Synisoma*, and *Euidotea*, all with a four-jointed palp of the maxillipede and one to four metasomatic segments.

Finally, in a fourth group we have *Edotia* and *Synidotea*, each with a three-jointed palp of the maxillipede and a single metasomatic segment and one suture. The Table on p. 71 summarizes these and other structural features.

Whilst there is fairly conclusive evidence to show that the genera of the first group are closely related to one another (*cf.* 19 & 10), I do not think that it is possible, in the present state of our knowledge, to state that a similar relationship is evident between the genera of the remaining groups.

As I have elsewhere pointed out (12 *a*), the classification of this interesting family of Isopoda is as yet very uncertain. The known genera and species in all probability constitute only a very small part of those actually existing.

The distribution of the members of this family, which contains some two dozen genera, including about one hundred and twenty-five species, as at present known, is curious. Miers (16) and the earlier writers all regarded them as having a wide distribution in all parts of the world, but being more abundant in temperate and colder seas than in the tropics. At that time the majority of species had been obtained in Northern latitudes, but of recent years many new species have been obtained from the Mid and Southern Pacific, Indian Ocean, and Antarctic. Thus, Ohlin (18) has described two new species of *Macrochiridothea* and two of *Edotia*, and a new species of *Erichsonella* from South America; Chilton (5), the curious *Idotea festiva* from New Zealand; Miss Richardson *, a new species of *Glyptonotus* from the Antarctic; Barnard (1, 2), three new species of *Paridotea* and one of *Synidotea* from South Africa. More recently † I have described a new species of *Synidotea* from the Indian Ocean, and I have two new species of *Crabyzos* from South Australia, in addition to a number of other forms from tropical localities not yet worked out.

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* Bull. Mus. Paris, 1906, p. 187.

† Rec. Indian Mus. vol. xiii. (1917) pt. 1, p. 1, pl. i.

There is no reason to suppose that the South Pacific and Antarctic Regions are any poorer in genera and species than the North Pacific and Arctic Regions, although but few have yet been obtained from the former regions. A careful study, now extending over some years, of the existing forms leads me to the conclusion that future investigations will undoubtedly tend to link together more closely the various genera of this family and the different families of the Valvifera.

As at present known the members of this suborder may conveniently be placed in two groups, viz.:—

i. ASTACILLINEA, nov.

Containing the families Astacillidæ, Stebbing, Chætiliidæ, Dana, and Amesopodidæ, Stebbing.

ii. IDOTEINEA, nov.

Containing the families Idoteidæ, Fabricius, Pseudidotheidæ, Ohlin, and Hologuathidæ, G. M. Thomson.

	1st Maxilla.	Maxillipede.	Metasome.	
	Number of Spines on Inner Lobe.	Number of Joints in Palp.	Number of	
			Segments.	Sutures.
Glyptonotus, Eights	6	5	5	
Symmius, Richardson	....	3 (?)	3	
Chiridotea, Harger	....	3	4	1
Macrochiridothea, Ohlin	....	3		
Mesidotea, Richardson	3	5	5	
Proidotea, Rac. & Sev.	?	?	5	
Chiriscus, Richardson	....	3 (?)	3	
Zenobiana, Stebbing	3	5	3–5	
Pentidotea, Richardson	3	5	3	1
Engidotea, Barnard	2	5	2	2
Cleantiella, Richardson	....	5	2	
Paridotea, Stebbing	3 or 4	5	1	3
Glyptidotea, Stebbing	3	5	1	3
Pentias, Richardson	3	5	1	3
Crabyzos, Spence Bate	3	5	1	2*
Idotea, Fabricius	3	4	3	1
Euidotea, Collinge	3	4	1	3
Colidotea, Richardson	....	4	1	1
Eusymmerus, Richardson	....	4	1	1
Erichsonella, Benedict	3 l. 4 r.	4	1	
Synisoma, Collinge	3	4	1	
Edotia, Guérin-Mén.	....	3	1	1
Synidotea, Harger	2	3	1	

* The second suture is very small in some species, scarcely visible on the dorsal side.

IV. SYNOPTIC TABLE OF THE GENERA DEALT WITH.

A. Coxal plates distinct on the 3 posterior segments of the mesosome.
a. Lateral margins of the cephalon entire. Eyes dorsally situated.
b. Flagellum of antennæ single-jointed.
c. Metasome composed of 3 segments.
d. Maxillipedes with a 3-jointed palp .... *Symmius*, Richardson.

B. Coxal plates distinctly separated on 2nd to 7th segments of the mesosome.
a. Lateral margins of the cephalon cleft. Eyes dorsally situated.
b. Flagellum of antennæ multiarticulate.
c. Metasome composed of 4 segments and 1 pair of sutures.
d. Maxillipedes with a 3-jointed palp .... *Chiridotea*, Harger.
c′. Metasome composed of 5 segments.
d′. Maxillipedes with a 5-jointed palp .... *Mesidotea*, Richardson.
a′. Lateral margins of the cephalon entire. Eyes situated dorso-laterally.
c″. Metasome composed of 3 segments and 1 pair of sutures .... *Pentidotea*, Richardson.
c‴. Metasome composed of a single segment and 3 pairs of sutures .... *Glyptidotea*, Stebbing.
Paridotea, Stebbing.
c′. Metasome composed of 3 segments and 1 pair of sutures.
d″. Maxillipedes with a 4-jointed palp.............. *Idotea*, Fabricius.
c″. Metasome composed of a single segment and 3 pairs of sutures .... *Euidotea*, Collinge.
b′. Flagellum of antennæ single-jointed.
c‴. Metasome composed of a single segment .... *Erichsonella*, Benedict.

C. Coxal plates not distinct on any mesosomatic segments.
a. Lateral margins of the cephalon entire. Eyes situated dorso-laterally.
b. Flagellum of antennæ rudimentary.
c. Metasome composed of a single segment and 1 pair of sutures.
d. Maxillipedes with a 3-jointed palp .... *Edotia*, Guérin-Mén.
b′. Flagellum of antennæ multiarticulate.
c′. Metasome composed of a single segment and 1 pair of sutures .... *Synidotea*, Harger.

V. LIST OF GENERA AND SPECIES EXAMINED

SYMMIUS, *Richardson.*

1. SYMMIUS CAUDATUS, *Richardson.*

Symmius caudatus, Richardson, Proc. U.S. Nat. Mus. vol. xxvii. (1904) p. 39, figs. 11-15.

This interesting species was described by Richardson in 1904, from specimens obtained from Japan. The only reference to the oral appendages is in the generic diagnosis, where it is stated "Maxillipedes with a three-jointed palp."

I have previously stated (10) that I question the accuracy of the figures given of this appendage (*op. cit.* p. 41, figs. 13 *a* & *b*). In these two figures Miss Richardson shows a 3-jointed palp; the basipodite, epipodite, and inner distal lobe united; and a very curious form of coxopodite, in all of which characters it is totally unlike the condition obtaining in any other genus of the family.

In the single specimen of this species in my collection, the oral appendages had been removed before it came into my possession. I am unable, therefore, to give a description or figures of either the first maxilla or the maxillipede.

CHIRIDOTEA, *Harger.*

2. CHIRIDOTEA CÆCA (*Say*). (Pl. 7. fig. 1.)

Idotea cæca, Say, Journ. Acad. Nat. Sci. Philad. vol. i. (1818) p. 424; Milne-Edwards, Hist. Nat. des Crust. vol. iii. (1840) p. 131; Harger & Verrill, Rept. U.S. Comms. Fish & Fisheries, 1873, pt. I. p. 569, pl. 5. fig. 22.

Chiridotea cæca, Harger, Amer. Journ. Sci. vol. xv. (1878) p. 374; Rept. U.S. Comms. F. & F. 1880, pt. VI. p. 338, pl. 4. figs. 16-19.

Glyptonotus cæcus, Miers, Journ. Linn. Soc., Zool. vol. xvi. (1881) p. 17.

Chiridotea cæca, Richardson, Bull. No. 54, U.S. Nat. Mus. 1905, p. 353, figs. 380, 381.

The Maxillipede (Pl. 7. fig. 1).—Both Harger and Richardson have figured the maxillipede of this species, but neither describes it. In both instances the figures are incorrect.

This appendage in the genus *Chiridotea* is characterized by the short wide epipodite, small basipodite, and a three-jointed palp, the second joint of which is unusually long.

In this species the whole appendage is extremely short. The coxopodite has the usual two joints of which the outermost is the larger. The basipodite is very small, having a straight inner margin and the outer one slightly expanded. Both the anterior and the posterior margin slope outwardly, but not to the extent shown in Harger's figure. The three-jointed palp is rather more than two and a half times the length of the basipodite: the first joint is small, the second very long, and the third smaller and more or less oval. Setæ spinous. The inner distal lobe extends forward as far as the middle of the second joint of the palp and has the usual setose and plain spines terminally. The epipodite is somewhat cone-shaped, very short, wider than the basipodite, and has its posterior margin excavate.

3. CHIRIDOTEA TUFTSII (*Stimpson*). (Pl. 7. fig. 2.)

Idotea tuftsii, Stimpson, Smithsonian Contrib. to Knowledge, vol. vi. (1853) p. 39; Harger & Verrill, Rept. U.S. Comms. F. & F. 1873, pt. I. pp. 340 & 569.

Chiridotea tuftsii, Harger, Amer. Journ. Sci. vol. xv. (1878) p. 374; Rept. U.S. Comms. F. & F. 1880, pt. VI. p. 340, pl. 4. figs. 20–23.

Glyptonotus tuftsii, Miers, Journ. Linn. Soc., Zool. vol. xvi. (1881) p. 18.

Chiridotea tuftsii, Richardson, Bull. No. 54, U.S. Nat. Mus. 1905, p. 354, figs. 382, 383.

The Maxillipede (Pl. 7. fig. 2).—The single specimen I have examined does not at all agree with either Harger's or Richardson's figures. I have no reason to doubt the identification of the species which was obtained at Cape Cod Bay, U.S.A., in 1879. A reference to the figure shows that in this specimen, whilst preserving most of the characters typical of *Chiridotea*, there are four joints in the palp.

MESIDOTEA, *Richardson*.

4. MESIDOTEA SABINI (*Kröyer*). (Pl. 7. figs. 3–5.)

Idotea sabini, Kröyer, Nat. Tidsskr. vol. ii. (1846–49) (s. 2) p. 401; G. O. Sars, Arch. f. Math. og Naturvidensk. vol. ii. (1877) p. 350.

Glyptonotus sabini, Miers, Journ. Linn. Soc., Zool. vol. xvi. (1881) p. 15, pl. 1. figs. 3–5; Richardson, Proc. U.S. Nat. Mus. vol. xxi. (1899) p. 844.

Chiridotea sabini, Stebbing, Ann. & Mag. Nat. Hist. (s. 7) vol. iv. (1899) p. 263.

Mesidotea sabini, Richardson, Bull. No. 54, U.S. Nat. Mus. 1905, p. 350, figs. 377–379.

Kröyer figures both of the maxillæ and the maxillipedes, the former, however, bear little or no resemblance to the actual form. In the first maxilla he shows an outer lobe with eight spines and an inner one with four, whilst in the second maxilla the two outer lobes are shown with four spines on each and a series of bluntly ending ones on the inner lobe. The maxillipede in his lower figure is fairly correct, but wrong in the upper one.

The First Maxilla (Pl. 7. fig. 3).—The outer lobe terminates in eleven spines, most of which are stout, and there are numerous setæ on the outer margin of the lobe, which extend downwards for some distance. The inner lobe terminates in two long setose spines and a small curved setule on the outer ventral border.

The Second Maxilla (Pl. 7. fig. 4).—The two outer lobes terminate in six and seven long spines respectively, most of these are serrated; the innermost lobe has sixteen to twenty setose spines, varying in size, the last one on the inner margin being the longest.

The Maxillipede (Pl. 7. fig. 5).—In this species this appendage is comparatively small, but of a very robust type and having its margins densely fringed with setæ and spines. The inner division of the coxopodite is small, almost cuboid. The basipodite is also very small, measuring only about half the length of the palp. Its anterior and posterior margins are obliquely cut away, sloping towards the outer margin; the inner margin is fringed with fine, closely-set setæ. The five-jointed palp has the first joint rather larger than in most species, the second joint is comparatively small, the third the largest and with a lobe-like extension on the inner side, the fourth joint is longer than the third, but much narrower, whilst terminally there is a small fifth joint. All the joints are fringed with setæ, which are extra long on the fifth joint. The inner distal lobe extends to the anterior border of the second joint of the palp and is fringed with setose spines terminally. The epipodite is almost circular and extends as far as the middle of the second joint of the palp. It is fringed with short, closely-set setæ.

PENTIDOTEA, *Richardson.*

5. PENTIDOTEA RESECATA (*Stimpson*). (Pl. 7. figs. 6, 7.)

Idotea resecata, Stimpson, Bost. Journ. Nat. Hist. vol. vi. (1857) p. 504, pl. 22. fig. 7; Miers, Journ. Linn. Soc., Zool. vol. xvi. (1881) p. 45.

Pentidotea resecata, Richardson, Bull. No. 54, U.S. Nat. Mus. 1905, p. 369, figs. 400, 401.

The First Maxilla (Pl. 7. fig. 6).—This appendage in this species has not previously been figured or described. The outer lobe terminates in twelve spines, the innermost five of which are denticulate; there is a long fine spine about the middle and then six stout curved spines on the outer side. The inner lobe terminates in three long setose spines and a setule on the outer anterior margin.

The Maxillipede (Pl. 7. fig. 7).—This appendage is greatly elongated in this genus and characterized by the large epipodite. Miss Richardson has given a figure of the maxillipede, but it is inaccurate in detail. The basipodite is narrow and greatly elongated and has straight inner, outer, and posterior margins. It is longer than the palp, which is five-jointed, the terminal joint being quite small. The inner distal lobe is narrow and the spines on its terminal margin setose. The epipodite is a large, elongated, wide plate extending forward as far as the middle of the third joint of the palp. It is slightly narrower anteriorly than posteriorly, but wider throughout than the basipodite.

6. PENTIDOTEA WOSNESENSKII (*Brandt*). (Pl. 7. figs. 8, 9.)

Idotea wosnesenskii, Brandt, in Middendorff's Sibirische Reise, vol. ii. (1851) Crust. p. 146.
Idotea hirtipes, Dana, U.S. Expl. Exped. vol. xiv. (II.) (1853) p. 704, pl. 46. fig. 6.
Idotea oregonensis, Dana, Proc. Acad. Nat. Sci. Philad. vol. vii. (1854) p. 175.
Idotea media, Dana, ibid. (1857) p. 175.
Idotea wosnesenskii, Miers, Journ. Linn. Soc., Zool. vol. xvi. (1881) p. 40; Richardson, Proc. U.S. Nat. Mus. vol. xxi. (1899) p. 846.
Pentidotea wosnesenskii, Richardson, Bull. No. 54, U.S. Nat. Mus. 1905, p. 370, figs. 402–404.

The First Maxilla (Pl. 7. fig. 8).—The outer lobe terminates in twelve stout curved spines, the outermost five being rather stronger than the remaining ones; none of them are denticulate. The inner lobe narrows considerably at its distal end and bears three slender setose spines.

The Maxillipede (Pl. 7. fig. 9).—Miss Richardson has given a figure of the maxillipede, but I find many points of difference. The basipodite is elongated and somewhat shield-shaped, being produced anteriorly at each side of the first joint of the palp and narrowed posteriorly on both the inner and outer margins. It is rather shorter than the length of the palp. All the five joints of the palp are large, the first and fifth being the smallest, the second and third are produced at their anterior margins, the latter more so than the former. The inner distal lobe is wide and surmounted by numerous setose and plain spines. The epipodite is a large wide plate, extending forward as far as the commencement of the third joint of the palp. It narrows a little toward the anterior or apical end and is wider than the basipodite.

7. PENTIDOTEA WHITEI (*Stimpson*). (Pl. 7. figs. 10, 11.)

Idotea whitei, Stimpson, Proc. Acad. Nat. Sci. Philad. (1864) p. 155; Miers, Journ. Linn. Soc., Zool. vol. xvi. (1881) p. 42.
Pentidotea whitei, Richardson, Bull. No. 54, U.S. Nat. Mus. 1905, p. 373, figs. 405, 406.

The First Maxilla (Pl. 7. fig. 10).—The outer lobe has twelve terminal spines, the outermost five being stout and curved, the sixth is straighter and more slender, and all the remaining ones, excepting the innermost, have each four or five blunt tooth-like processes. On the ventral surface there is a large setule set in a cup-shaped articular cavity. There are a few setæ on the outer margin. The inner lobe more closely resembles that of *P. resecata* than *P. wosnesenskii*, being wide at its distal end. It has three setose spines, and a short strong setule on its inner anterior margin.

The Maxillipede (Pl. 7. fig. 11).—This appendage resembles somewhat that described in *P. wosnesenskii*, though larger and generally more robust. Miss Richardson's figure does not show the divisions of the coxopodites or those between the basipodite and the inner distal lobe, and the shape of the former is scarcely correct.

The basipodite is rather shorter and wider than in *P. wosnesenskii* and as wide as the greatest transverse dimension of the epipodite. The five-jointed palp is considerably longer than the basipodite and all the joints wider and longer than in the preceding species, the fifth joint is comparatively much larger than in either of the two species of this genus described above. The inner distal lobe is slightly narrower than in *P. wosnesenskii*, but otherwise very similar. The epipodite is a large flat, elongated plate, narrowing somewhat towards its apical margin, and extending forward to almost the middle of the third joint of the palp.

GLYPTIDOTEA, *Stebbing*.

8. GLYPTIDOTEA LICHTENSTEINI (*Krauss*). (Pl. 7. figs. 12, 13.)

Idotea lichtensteini, Krauss, Südafrik. Crust. 1843, p. 62, pl. iv. fig. 4; Miers, Journ. Linn. Soc., Zool. vol. xvi. (1881) p. 64.

Glyptidotea lichtensteini, Stebbing, Sth. Afr. Crust. pt. II. 1902, p. 57, pl. 10.

Stebbing was the first to describe and figure the oral appendages, he states: "First maxillæ.—The outer plate is surmounted by eleven curved spines, the outermost but one being the strongest, the innermost six slender, forming two sets, each consisting of three graduated spines. The inner plate has three plumose setæ on the narrow apex. . . . Maxillipedes.—The inner margin of the first joint forms a rounded process beset with plumose setæ; its external part forms a broad base for the large distally narrowed epipod. The second joint is elongate, its apical process, distally fringed with setæ, reaches beyond the second joint of the palp and somewhat above its base has a strong spine-hook, nearly at the level reached by the apex of the epipod. The first joint of the palp is small, the second widened cup-like, with the inner margin much longer than the outer, the third joint similar but larger, and with less difference between the two margins; the fourth joint is much the longest, oval, but with truncate apex, on which is placed the small, but very distinct, oval fifth joint, this like the three preceding joints having setæ on the inner margin."

With many other writers Mr. Stebbing does not distinguish between the two divisions of the coxopodite, and the inner distal lobe, which is distinct from the basipodite.

The First Maxilla (Pl. 7. fig. 12).—In all the specimens I have examined I find twelve terminal spines on the outer lobe and a large setule, set in a cup-shaped cavity, on the ventral side; further, on the inner lobe, in addition to the three setose spines, there are two setules, *The Maxillipede* (Pl. 7. fig. 13).—This appendage in this species shows a strong resemblance to the condition obtaining in the genus *Pentidotea*, only it is less robust and considerably narrower. The divisions of the coxopodite are large and slightly overlap one another. The basipodite is narrow and elongated, with a straight inner margin and narrowest about its middle. The posterior margin slopes upwards and outwards. The five-jointed palp presents all the characteristic features seen in *Pentidotea*, and is half again as long as the basipodite. The inner distal lobe reaches almost to the end of the extended inner margin of the third lobe of the palp. There are a number of setose and plain spines distally of a rather more robust type than in *Pentidotea*. The epipodite proximally is wider than the basipodite, but its distal third narrows considerably, becoming bluntly pointed at its apical margin. It extends forward as far as the anterior outer margin of the second joint of the palp.

It is somewhat doubtful whether or not this species is entitled to separate generic rank or whether it is not synonymous with *Paridotea*, Stebbing. In both genera the palp of the maxillipedes consists of five joints, and the metasome is composed of a single segment and three pairs of sutures. The most striking difference between the two genera is seen, perhaps, in the form of the cephalon.

IDOTEA, *Fabricius.*

9. IDOTEA RECTILINEA, *Lockington.* (Pl. 7. figs. 14, 15.)

Idotea rectilinea, Lockington, Proc. Cal. Acad. Sci. vol. vii. (1877) p. 36; Richardson, Proc. U.S. Nat. Mus. vol. xxii. (1900) p. 131, fig. 5 *c*; Bull. No. 54, U.S. Nat. Mus. 1905, p. 360, figs. 389–391.

The First Maxilla (Pl. 7. fig. 14).—This appendage has not previously been described or figured in this species. The outer lobe terminates in twelve strong curved spines, of which three or four at the inner side are denticulate. The inner lobe has three setose spines and a small curved setule on the ventral outer margin; there are numerous long fine setæ on the inner margin.

The Maxillipede (Pl. 7. fig. 15).—Miss Richardson gives a figure of this appendage in which the coxopodite is shown as a single piece and the general shape is scarcely correct.

The coxopodite consists of two large stout nodules, one lying at the base of the epipodite and the other at the base of the basipodite. In all of the specimens examined these had the large cuboid form shown in fig. 15. The anterior margin of the basipodite is produced slightly on each side of the first joint of the palp. Its inner, outer, and posterior margins are almost straight. The palp is composed of four joints, of which the third is rather smaller than usual. The inner distal lobe has an almost straight anterior margin, it slopes outwardly, becoming wide at the base. There are a number of setose spines on the anterior margin. The epipodite is slightly narrower than the basipodite. It extends forward slightly beyond the anterior outer margin of the second joint of the palp and becomes a little narrower towards its apical margin.

10. IDOTEA PHOSPHOREA, *Harger*. (Pl. 7. figs. 16–18; Pl. 8. figs. 19–23.)

Idotea phosphorea, Harger with Verrill, Rept. U.S. Comms. F. & F. 1873, pt. i. p. 569; Harger, ibid. 1880, pt. vi. p. 347, pl. 5. figs. 27–29.
Idotea marina, var. *phosphorea*, Miers, Journ. Linn. Soc., Zool. vol. xvi. (1881) p. 31.
Idothea phosphorea, Richardson, Bull. U.S. Nat. Mus. 1905, p. 367, figs. 398, 399.

Considerable difference of opinion exists amongst carcinologists as to the specific identity of this species. It was described by Harger in 1873, and in 1880 he gave figures of the animal, the antenna, the maxillipede, the first two walking limbs, the second metasomatic appendage, and the uropod. The original description is as follows:—

"The head is narrowed behind. The eyes are of moderate size. The flagellum of the antennæ is shorter than the peduncle, and consists of about ten to fourteen segments. The maxillipeds have the external lamella broader than in the preceding species [*I. baltica*], with its inner margin straight and its outer margin curving pretty regularly to a slightly attenuated tip.

"The epimera of the second, third, and fourth pairs are rounded behind, and those of the last three pairs are less acute than in *I. baltica* *.

"Pleon ovate, a little constricted near the middle and pointed, its three proximal segments rather less acute than in the preceding species. The basal plate of the operculum tapers towards the end, and the terminal plate is triangular, a little longer than broad. The stylet on the second pair of pleopods in the male is slender, nearly straight, surpasses the lamella to which it is attached, and is obliquely truncate.

"Length 25 mm.; breadth 7 mm."

Miers regarded this species as a variety of *I. baltica* (Pallas), and remarks: "There appears to be no sufficient reason to distinguish *Idotea granulosa* of Rathke . . . . from the American *I. phosphorea*."

Whilst *I. phosphorea* is no doubt closely related to *I. granulosa*, Rathke, which is now regarded as a valid species, I am of opinion that there are sufficient well-defined structural characters which clearly separate it from this latter species. Of these, the most important are, the form of the cephalon, the coxal plates of the mesosome, and the form of the metasome. In addition, the antennules, the antennæ, the first maxillæ, and the maxillipedes also exhibit differences. Finally, in all the specimens of *I. granulosa* that I have examined the dorsal surface of the body never shows tubercles;

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* Termed *I. irrorata* by Harger.

it is either finely granulated or almost smooth, whereas in all the specimens of *I. phosphorea* that I have seen there are large lateral and median tubercles. Harger states, "the body, especially of the young, is rough and tubercular along the median line and often, also, laterally. Older specimens are much smoother, losing their large median tubercles, but never becoming as smooth as in" *I. baltica*. I have seen no examples measuring more than 22 mm. in length, and in all of these both the lateral and median tubercles are quite prominent.

A comparison of Sars's figures (22, pl. 34. fig. 1) or those given by myself (12 a, pl. 5. figs. 48–58) of *I. granulosa*, with those given by Harger (13, pl. 5. figs. 27–29) of *I. phosphorea*, at once show the difference in the form of the terminal segment of the metasome, the coxal plates of the mesosome, &c.

In the form of the cephalon (Pl. 8. fig. 16) the differences from *I. granulosa* are very marked, and are at once apparent in the width and the deep transverse groove, anterior to the posterior margin. The eyes are larger and situated more anteriorly, whilst the lateral margins posterior to the eyes curve inwards.

The antennule (Pl. 8. fig. 17) is shorter and more robust in this species than in *I. granulosa*, as also the antenna (fig. 18).

In *I. granulosa* I have described (12 a) the coxal plates of the mesosome as occupying the anterior two-thirds of the lateral margin of the second segment, the third rather more, and the remainder the whole of the lateral margins, increasing in breadth from the fourth to the seventh segments. Sars (22) speaks of them as being "comparatively small."

In *I. phosphorea*, whilst occupying approximately the same proportion of each segment, they are slightly wider, the external margin being more expanded, so that those of the second, third, and fourth segments are roughly triangular, the apex of the triangle being rounded. Those on the fifth, sixth, and seventh segments have a sloping margin from the anterior to the posterior angle, whereas in *I. granulosa* the margins are almost truncate.

Harger (13) remarks that young specimens resemble the young of *I. irrorata* (= *baltica*), but that they can be distinguished by the coxal plates of the second and third mesosomatic segments, which do not occupy the whole of the posterior border of the segment. I have compared examples of *I. phosphorea* of from 10 to 15 mm. in length with similar sized specimens of *I. baltica*, but I must confess that I fail to note any resemblance between the two, the general shape and coloration at once serving to separate them.

Although Harger examined large numbers of specimens from twenty different localities, ranging from the New England coast northwards to Halifax, Nova Scotia, and the Gulf of St. Lawrence, and southwards as far as Cape Cod, he never observed a striped pattern of coloration, so common in *I. baltica*, with which species it was found associated, the colour being usually dark green or brownish, with patches of yellow or whitish, transversely or obliquely arranged.

The First Maxilla (Pl. 8. fig. 19) has the outer lobe strongly curved inwards. There are eleven spines and a fine setule on the ventral surface. Four or five of the innermost spines are denticulate. The inner lobe is fairly large and has three stout setose spines terminally and a setule on the anterior outer margin.

The Maxillipede (Pl. 8. fig. 20).—Of the two figures given by Harger and Richardson of this appendage, that of the former is the better, although both differ considerably from the condition noted in the specimens I have examined. The coxopodite has the two usual divisions. The basipodite is elongated and narrower than the epipodite. The four-jointed palp is half again as long as the basipodite, the first and third joints are small, whilst the second is longer and greatly expanded at the anterior margin on the outer side. The inner distal lobe extends forward almost to the end of the third joint of the palp, terminally it is surmounted with a number of setose and plain spines. The epipodite is shown by Harger with an almost straight inner margin and a narrow, bluntly pointed apical portion lying beneath the third joint of the palp. In all the specimens I have examined, both the inner and outer margins are curved outwards, and with the apical portion slightly narrower and not extending beyond the second joint of the palp.

The metasome (Pl. 8. fig. 22) is composed of two short joints, a single suture, and the large terminal segment. This latter is more triangular than in *I. granulosa*, rather shorter, and shows a faint constriction about its middle, then widening slightly, it terminates somewhat abruptly in a sharp point.

The uropod (Pl. 8. fig. 23) is characterized by the triangular-shaped endopodite, which is rather longer than wide.

PARIDOTEA, *Stebbing*.

11. PARIDOTEA UNGULATA (*Pallas*). (Pl. 8. figs. 24, 25.)

Oniscus ungulatus, Pallas, Spicil. Zool. vol. ix. (1772) p. 62, pl. 4. fig. 11.
Idotea ungulata, Lamarck, Hist. Anim. sans Vert. vol. v. (1818) p. 160.
Idotea lalandii, Milne-Edwards, Hist. Nat. Crust. vol. iii. (1840) p. 132, pl. 31. fig. 7; Krauss, Südafrik. Crust. 1843, p. 61.
Idotea affinis, Milne-Edwards, Hist. Nat. Crust. vol. iii. (1840) p. 133; Krauss, Südafrik. Crust. 1843, p. 61.
Idotea edwardsii, Guérin-Méneville, Icon. Règne Anim. 1829-44, Crust. p. 33.
Idotea nitida, Heller, Verhandl. zool.-bot. Ges. Wien, 1861, p. 497.
? ***Idotea excavata***, Haswell, Proc. Linn. Soc. N.S.W. vol. vi. (1882) p. 2.

Idotea ungulata, Miers, Journ. Linn. Soc., Zool. vol. xvi. (1881) p. 52; Chilton, Trans. New Zealand Inst. vol. xxii. (1890) p. 196.
Paridotea ungulata, Stebbing, Sth. Afr. Crust. 1900, pt. I. p. 53.

The only two references to the oral appendages of this species are a figure of the mandible and the maxillipedes given by Milne-Edwards, and a short description of all the appendages by Stebbing. In this latter account the author remarks: "The first maxillæ have six strongly plumose setæ on the narrow inner plate, and ten short apical spines on the outer." In the description of the maxillipede the palp is spoken of as consisting of *four* joints. As will be seen from the following description and accompanying figures, I find many differences from Mr. Stebbing's account.

The First Maxilla (Pl. 8. fig. 24).—This appendage is very large in this species. The outer lobe has five stout curved spines on the outer side, then a thin fine curved one and a further six, not so strong as those on the outer side; there is also a long setule, set in a cup-shaped cavity, on the ventral surface. The inner lobe is wide and has four stout setose spines terminally, and a small setule on the middle of the ventral surface close to the anterior margin. In none of the nine specimens examined was any variation in the number of spines observed.

The Maxillipede (Pl. 8. fig. 25).—This appendage is considerably elongated in this genus. The two divisions of the coxopodite are small, as also the basipodite, which posteriorly terminates in a blunt point, with a straight outer margin; anteriorly it flanks the first joint of the palp on both sides; the outer margin gradually curves inwards towards the posterior end. The palp is nearly twice the length of the basipodite. The first joint is small, the second more elongated and slightly expanded laterally, the third joint is still longer and more expanded laterally particularly on the inner side, the fourth joint is the longest, and this and the smaller terminal joint are both densely setose on their inner margins. There are also a few setæ on the inner margin of the third and second joints. The inner distal lobe extends forward as far as the middle of the third joint of the palp. It has an outwardly sloping anterior margin from which arise a number of setose spines; there are three coupling-hooks towards the base of the inner margin. The epipodite posteriorly is wider than the basipodite, narrowing anteriorly, and then sloping inwardly its apical portion terminates in a blunt point. It extends forward to about the middle of the third joint of the palp.

PARIDOTEA UNGULATA (*Pallas*) var. nov. ATROVIRENS.

Whole of the body a very dark olive-green, almost black. Length 40 mm.

Hab. Shore-pools, Brighton, Victoria, Australia: Dec. 18, 1893 (*J. J. Lister*).

Type. In the University Museum of Zoology, Cambridge.

12. PARIDOTEA RETICULATA, *Barnard*. (Pl. 8. figs. 26, 27.)

Paridotea reticulata, Barnard, Ann. Sth. Afr. Mus. vol. x. (1914) p. 424, pl. 36 D.

Barnard, in describing this beautiful species, states: "The mouth-parts resemble those of *P. ungulata*, except that the lateral margins of the epistome are angular, not evenly convex, and the inner lobe of the first maxilla has only three plumose setæ."

The First Maxilla (Pl. 8. fig. 26).—The outer lobe terminates in twelve spines, three or four of the innermost being denticulate. The inner lobe is narrower than in *P. ungulata* and has only three terminal setose spines and a single setule on the anterior outer margin.

The Maxillipede (Pl. 8. fig. 27).—Whilst bearing a strong resemblance to the maxillipede of *P. ungulata*, this appendage in *P. reticulata* is rather more robust and setose. The basipodite is wider on its posterior margin and more obliquely cut away anteriorly. The second joint of the palp is smaller than in *P. ungulata* and the third longer and wider. The epipodite is about the same width as the basipodite, but narrows considerably towards its apical end. The whole appendage is densely setose, and there are a series of strong spines on the outer expanded margin of the third joint of the palp.

13. PARIDOTEA RUBRA, *Barnard*. (Pl. 8. figs. 28, 29.)

Paridotea rubra, Barnard, Ann. Sth. Afr. Mus. vol. x. (1914) p. 426, pl. 37 A.

The mouth-parts of this species have not hitherto been figured. Barnard's description is brief—he states: "First maxilla, outer plate with ten spines, the two innermost denticulate, inner plate with three plumose setæ. . . . Maxillipede seven-jointed, epipod reaching to the end of the fourth joint, apex incurved."

The First Maxilla (Pl. 8. fig. 28).—The outer lobe terminates in ten spines, the outermost one is smaller than the second one, and the two innermost are faintly denticulate; the inner lobe is narrow and has three setose spines and a prominent setule.

The Maxillipede (Pl. 8. fig. 29).—The two divisions of the coxopodite are small. The basipodite is narrow and elongated, with both inner and outer margins almost straight, the posterior margin is obliquely cut away towards the epipodite, anteriorly the segment flanks the first joint of the palp on both sides. The five-jointed palp is typical of the genus. The inner distal lobe is rather longer than in the preceding species. The epipodite is slightly narrower than the basipodite, excepting at its base; it is curved inwards anteriorly and extends as far as the middle of the third joint of the palp, not to the end of the fourth joint as stated by Barnard.

14. PARIDOTEA FUCICOLA, *Barnard*. (Pl. 8. figs. 30, 31.)

Paridotea fucicola, Barnard, Ann. Sth. Afr. Mus. vol. x. (1914) p. 427, pl. 36 A.

Barnard has figured the maxillipede, but not altogether satisfactorily.

The First Maxilla (Pl. 8. fig. 30).—This appendage differs from that in *P. rubra* in having more denticulate spines on the outer lobe and in the presence of a long setule on the inner ventral surface. It is also densely setose on both the inner and the outer margins, the setæ on the inner margin being strong and spine-like. The inner lobe differs only in the position of the setule, which in this species is smaller and situated on the outer anterior margin.

The Maxillipede (Pl. 8. fig. 31).—Excepting that it is much smaller and not so elongated, the maxillipede is very like that of *P. rubra*.

EUIDOTEA, gen. nov.

Body narrow-oblong, not keeled, and nearly smooth. Cephalon anteriorly emarginate, lateral lobes somewhat prominent. Maxillipedes with a palp composed of four joints. Coxal plates narrow, in the second, third, and fourth mesosomatic segments they occupy a little more than half of the lateral margins, in the fifth they occupy almost the whole of the lateral margins, and in the sixth and seventh segments extend from the anterior to the posterior angle. Metasome composed of a single segment and three lateral sutures.

15. EUIDOTEA PERONII (*Milne-Edwards*). (Pl. 8. figs. 32, 33.)

Idotea peronii, Milne-Edwards, Hist. Nat. Crust. vol. iii. (1840) p. 133; Miers, Journ. Linn. Soc., Zool. vol. xvi. (1881) p. 55; Chilton, Trans. New Zealand Inst. vol. xxii. (1890) p. 199.

Idotea distincta, Guérin-Méneville, Icon. Règne Anim. 1829–44, Crust. p. 33.

Idotea stricta, Dana, U.S. Expl. Exped. 1853, Crust. ii. p. 704, pl. 46. fig. 7; Miers, Journ. Linn. Soc., Zool. vol. xvi. (1881) p. 62.

Idotea caudacuta, Haswell, Proc. Linn. Soc. N.S.W. vol. vi. (1882) p. 1, pl. 4. fig. 4.

Paridotea peronii, Stebbing, Ann. Sth. Afr. Mus. vol. vi. (1910) p. 433.

This species was placed by Stebbing (24, p. 433) in the genus *Paridotea*, but an examination of the oral appendages at once shows that it cannot remain there, neither can it be placed in the genus *Idotea*, Fabr.; I have, therefore, proposed for its reception the new genus *Euidotea*.

The First Maxilla (Pl. 8. fig. 32).—The outer lobe terminates in twelve stout spines, free of any denticulation, and a single fine spine; the inner lobe has three setose spines, and three setules on its ventral surface.

The Maxillipede (Pl. 8. fig. 33).—There are two somewhat large divisions of the coxopodite. The basipodite is rather short, but on its inner side extends for some little distance beyond the first joint of the palp. It is about the same width as the epipodite and shorter than the palp. The four-jointed palp has the first joint small, the second joint longer than the third though not so expanded laterally, and the fourth joint considerably larger and oval in shape. The inner distal lobe is elongated, extending almost to the end of the third joint of the palp; terminally it has some strongly developed plain spines and a number of setose ones. The epipodite extends just beyond the anterior margin of the second joint of the palp.

ERICHSONELLA, *Benedict*.

16. ERICHSONELLA ATTENUATA (*Harger*). (Pl. **8**. fig. 34; Pl. **9**. fig. 35.)

Erichsonia attenuata, Harger with Verrill, Rpt. U.S. Comms. F. & F. 1873, pt. I. p. 570, pl. 6. fig. 27; Harger, ibid. 1880, pt. VI. p. 356, pls. 6, 7. figs. 36, 37.

Erichsonella attenuata, Richardson, Bull. No. 54, U.S. Nat. Mus. 1905, p. 400, figs. 447, 448.

The First Maxilla (Pl. **8**. fig. 34).—The outer lobe terminates in ten spines, the middle ones being the largest, two or three of the innermost are faintly denticulate. The inner lobe has the anterior margin sloping inwardly and has sometimes four and sometimes three setose spines and a setule on the outer margin; the inner margin is setose.

The Maxillipede (Pl. **9**. fig. 35).—Miss Richardson's figure shows three divisions of the coxopodite, but I have failed to find more than two. The basipodite is rather short and a little narrower than the epipodite. The palp has four wide joints, the first being small and the second and third cup-shaped and gradually enlarging, their inner margins are widely expanded, the fourth joint (the largest) is oval in shape. The setæ are small and few in number. The inner distal lobe extends almost as far as the anterior margin of the third joint of the palp. The epipodite is almost truncate at its posterior margin and narrows a little anteriorly and extends just beyond the middle of the third joint of the palp.

Synoptic Key to the Species of the Genus Synidotea.

A. Terminal segment of metasome emarginate or notched.	
a. Lateral cephalic lobes well developed.	
b. Frontal spines overhanging frontal lobe.	
c. Outline of metasome triangular	*S. hirtipes* (Milne-Edw.). *S. pallida*, Benedict.
b'. Frontal spines absent.	
c'. Outline of metasome subparallel..................	*S. nebulosa*, Benedict.
c''. Outline of metasome arcuate	*S. angulata*, Benedict.
c'''. Outline of mesosome subtriangular.	
d. Outline of metasome subparallel	*S. marmorata* (Packard).
d'. Outline of mesosome strongly arcuate	*S. bicuspida* (Owen).

B. Terminal segment of metasome produced as a blunt spine.
  a. Lateral cephalic lobes small.
    b. Frontal spines not on the margin ... . *S. nodulosa* (Kröyer).
    b'. Frontal spines on the margin .... *S. lævis*, Benedict.

SYNIDOTEA, *Harger*.

17. SYNIDOTEA HIRTIPES (*Milne-Edwards*). (Pl. 9. figs. 36, 37.)

Idotea hirtipes, Milne-Edwards, Hist. Nat. Crust. vol. iii. (1840) p. 134; Krauss, Sudafrik. Crust. 1843, p. 61.

Edotia hirtipes, Miers, Journ. Linn Soc., Zool. vol. xvi. (1881) p. 68.

Synidotea hirtipes, Benedict, Proc. Acad. Nat. Sci. Philad. 1897, p. 403; Stebbing, Sth. Afr. Crust. 1902, pt. ii. p. 60.

Stebbing has described the oral appendages of this species in great detail. He states: "The first maxillæ have the outer plate surmounted by ten or sometimes eleven spines, some of which are denticulate, none very powerful. The inner plate is narrow at both ends, and has at the apex only two setæ, which are rather long, and, as usual, setose.

"The maxillipedes have the first joint short, the epipod nearly parallel-sided, not reaching the apex of the process of the second joint, though extending considerably beyond the first joint of the palp; its upper margin slopes inward. The process of the second joint is shaped as commonly in the Amphipoda Gammaridea, and similarly fringed with setæ on the inner and apical margins, but here it is tied to its fellow, each member of the pair carrying a strong spine-hook for grappling the other. The first joint of the palp is small and rather obscure, the second is very large, widening distally, its distal margin flatly rounded on the inner part and externally forming a little free projection. The third joint is also very large, its inner margin almost continuous with that of the preceding joint, feebly convex, fringed with short spines, its outer margin strongly convex, fringed with setæ-like spines, some of which also stand out from the surface."

The First Maxilla (Pl. 9. fig. 36).—In none of the specimens that I have examined have there been more than ten spines on the outer lobe, in addition to which there is a long setule set in a cup-shaped cavity on the ventral surface of the lobe. In a like manner there are three setules on the ventral surface of the narrow inner lobe, the two setose spines of which are rather longer than in most species.

The Maxillipede (Pl. 9. fig. 37).—This appendage in the genus *Synidotea* is characterized by the large size of the second and third lobes of the palp. In *S. hirtipes* the two divisions of the coxopodite are small. The basipodite has both its inner and outer margins almost straight, the posterior and anterior ones slope outwards. The three-jointed palp is almost twice the length of the inner margin of the basipodite. The first joint is small, the second and third joints are very large. The inner distal lobe extends forward slightly beyond the middle of the second joint of the palp, and distally it has a number of setose spines. The epipodite is a wide flattened plate, with almost parallel sides; it is wider than the basipodite. Its apical portion curves outwardly slightly and extends forward as far as a point a little beyond the middle of the second joint of the palp.

18. SYNIDOTEA PALLIDA, *Benedict*. (Pl. 9. figs. 38, 39.)

Synidotea pallida, Benedict, Proc. Acad. Nat. Sci. Philad. 1897, p. 396; Richardson, Bull. No 54, U.S. Nat. Mus. 1905, p. 378, figs. 412, 413.

The First Maxilla (Pl. 9. fig. 38).—The outer lobe exhibits a strong inward curve. It has eight terminal spines, all of which are denticulate, and there are a few setæ on the inner anterior margin. The inner lobe is comparatively small; terminally there are two long setose spines.

The Maxillipede (Pl. 9. fig 39).—Miss Richardson's figure of the maxillipede of this species is incomplete and very unlike the actual appendage. The divisions of the coxopodite are small. The basipodite is small, but does not slope outward quite so much as in the preceding species, and the second joint of the palp is smaller, the third joint is twice the length of the second one; the inner distal lobe is also narrower than in *S. hirtipes*. The epipodite is a wide flattened plate with its apical portion narrowed and sloping outwards; it extends as far forward as the anterior margin of the second joint of the palp.

19. SYNIDOTEA NEBULOSA, *Benedict*. (Pl. 9. figs. 40, 41.)

Synidotea nebulosa, Benedict, Proc. Acad. Nat. Sci. Philad. 1897, p. 397; Richardson, Proc. U.S. Nat. Mus. vol. xxi. (1899) p. 848; Bull. No. 54, U.S. Nat. Mus. 1905, p. 381, figs. 416, 417.

The First Maxilla (Pl. 9. fig. 40).—The outer lobe has a strong inward curve. There are ten terminal spines, most of which are denticulate; there are a few setæ on both the outer and inner margins. The anterior portion of the inner lobe is roughly triangular with the distal end obliquely cut away and terminating in two stout setose spines.

The Maxillipede (Pl. 9. fig. 41).—The shape of the basipodite at once serves to separate this species from any other member of the genus. The second joint of the palp is very large, but the anterior lateral margins are not so expanded as in *S. hirtipes*.

20. SYNIDOTEA ANGULATA, *Benedict*. (Pl. 9. figs. 42, 43.)

Synidotea angulata, Benedict, Proc. Acad. Nat. Sci. Philad. 1897, p. 395; Richardson, Bull. No. 54, U.S. Nat. Mus. 1905, p. 382, figs. 418, 419.

The First Maxilla (Pl. 9. fig. 42).—The strong inner curve of the outer lobe is not so pronounced in this species. There are ten terminal spines, most of which are faintly denticulate. The anterior portion of the inner lobe is oval in shape with two setose spines, longer and more slender than those of *S. nebulosa*.

The Maxillipede (Pl. 9. fig. 43) agrees very closely with that of *S. nebulosa*, excepting that it is more robust and larger. The third lobe of the palp is more stunted and the basipodite much longer.

21. SYNIDOTEA MARMORATA (*Packard*). (Pl. 9. figs. 44, 45.)

Idotea marmorata, Packard, Mem. Bost. Soc. Nat. Hist. vol. i. (1867) p. 296, pl. 8. fig. 6.
Idotea bicuspida, Streets & Kingsley, Bull. Essex Inst. vol. ix. (1877) p. 108.
Synidotea bicuspida, Harger, Proc. U.S. Nat. Mus. vol. ii. (1879) p. 160; Rept. U.S. Comms. F. & F. 1880, pt. vi. p. 352.
Edotia bicuspida, Miers, Journ. Linn. Soc., Zool. vol. xvi. (1881) p. 66.
Synidotea marmorata, Benedict, Proc. Acad. Nat. Sci. Philad. 1897, p. 392; Richardson, Bull. No. 54, U.S. Nat. Mus. 1905, p. 384, figs. 422, 423.

The First Maxilla (Pl. 9. fig. 44).—Both of the lobes in this species are comparatively small. The outer one is abruptly narrowed posteriorly; anteriorly there are eight spines, all of which are denticulate. Setæ are present on both the inner and outer margins for a short distance.

The Maxillipede (Pl. 9. fig. 45).—This appendage bears a strong resemblance to that of *S. nebulosa*; there are, however, slight differences in the form of the basipodite and the second lobe of the palp.

22. SYNIDOTEA BICUSPIDA (*Owen*). (Pl. 9. figs. 46, 47.)

Idotea bicuspida, Owen, Crust. of the 'Blossom,' 1839, p. 92, pl. 27. fig. 6.
Idotea pulchra, Lockington, Proc. Cal. Acad. Sci. vol. vii. (1877) p. 44.
Synidotea incisa, G. O. Sars, Crust. et Pycnog. nova etc., 1880, no. 8.
Edotia bicuspida, Miers, Journ. Linn. Soc., Zool. vol xvi. (1881) p. 66.
Synidotea bicuspida, G. O. Sars, Crust. Norweg. Nth. Atlantic Exp. 1885, vol. i. p. 116, pl. 10. figs. 24–26; Benedict, Proc. Acad. Nat. Sci. Philad. 1897, p. 391; Richardson, Bull. No. 54, U.S. Nat. Mus. 1905, p. 385, fig. 424.

The oral appendages of this species have not previously been described or figured. They exhibit a relationship to *S. marmorata*, but differ from those in that species in being larger and of a more robust type.

The First Maxilla (Pl. 9. fig. 46).—The outer lobe is somewhat thickened and has ten spines, most of which are denticulate; there are a few setæ on the inner anterior margin. As in *S. marmorata*, the anterior end of the inner lobe is somewhat triangular in shape, but the inner margin is almost straight. There are two long setose spines, and a setule on the anterior inner margin.

The Maxillipede (Pl. **9**. fig. 47).—The form of this appendage in *S. bicuspida* approaches very closely to that found in *S. pallida*, only it is much larger and the third lobe of the palp is comparatively smaller, and also shorter than the second joint.

23. Synidotea nodulosa (*Kröyer*). (Pl. **9**. figs. 48, 49.)

Idotea nodulosa, Kröyer, Naturhist. Tidsskrift, vol. ii. (1846) p. 100; Voy. en Scand. Crust. 1849, pl. 26. fig. 2.

Synidotea nodulosa, Harger, Rept. U.S. Comms. F. & F. 1886, pt. vi. p. 351, pl. 6. figs. 33–35.

Edotia nodulosa, Miers, Journ. Linn. Soc., Zool. vol. xvi. (1881) p. 67.

Synidotea nodulosa, Benedict, Proc. Acad. Nat. Sci. Philad. 1897, p. 398; Richardson, Bull. No. 54, U.S. Nat. Mus. 1905, p. 388, figs. 429, 430.

The First Maxilla (Pl. **9**. fig. 48).—There are ten sharply pointed spines on the outer lobe, the three most ventral of which are denticulate; the inner lobe has two long setose spines and a single setule on the anterior outer margin.

The Maxillipede (Pl. **9**. fig. 49) agrees very closely with that of *S. bicuspida*; the epipodite, however, is rather longer and has its apical portion more pointed. The inner margin of the basipodite anteriorly is produced into a number of serrations.

24. Synidotea lævis, *Benedict*. (Pl. **9**. figs. 50, 51.)

Synidotea lævis, Benedict, Proc. Acad. Nat. Sci. Philad. 1897, p. 399; Richardson, Bull. No. 54, U.S. Nat. Mus. 1905, p. 389, figs. 431, 432.

The First Maxilla (Pl. **9**. fig. 50).—The outer lobe has a well-marked slope on its outer side and has eight terminal spines, two or three of which are denticulate; the inner lobe is somewhat triangular anteriorly, as in *S. nebulosa*, and has two long setose spines.

The Maxillipede (Pl. **9**. fig. 51).—This appendage in this species is characterized by the great development of the second joint of the palp. It is the longest of the three, and anteriorly considerably wider than long, owing to the great expansion of the anterior lateral margins. The epipodite is similar in shape to that in *S. marmorata*, only somewhat shorter. The inner margin of the basipodite is anteriorly continued forward for some little distance beyond the first joint of the palp.

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EXPLANATION OF THE PLATES.

No attempt has been made to introduce the exact number of setæ into the different figures.

Plate 7.

Fig. 1. *Chiridotea cæca* (Say). Ventral view of the right maxillipede. × 38.

2. —— *tuftsii* (Stimpson). Ventral view of the left maxillipede. × 38.

3. *Mesidotea sabini* (Kröyer). Ventral view of the terminal portions of the inner and outer lobes of the right first maxilla. × 19.

4. —— —— Ventral view of the terminal portion of the second maxilla. × 19.

5. —— —— Ventral view of the right maxillipede. × 9.

6. *Pentidotea resecata* (Stimpson). Ventral view of the terminal portions of the inner and outer lobes of the right first maxilla. × 19.

7. —— —— Ventral view of the left maxillipede. × 7·5.

8. —— *wosnesenskii* (Brandt). Ventral view of the terminal portions of the inner and outer lobes of the right first maxilla. × 19.

9. —— —— Ventral view of the right maxillipede. × 19.

10. —— *whitei* (Stimpson). Ventral view of the terminal portions of the inner and outer lobes of the left first maxilla. × 38.

11. —— —— Ventral view of the left maxillipede. × 19.

Fig. 12. *Glyptidotea lichtensteini* (Krauss). Ventral view of the terminal portions of the inner and outer lobes of the right first maxilla. × 38.
13. —— —— Ventral view of the left maxillipede. × 12.
14. *Idotea rectilinea*, Lockington. Ventral view of the terminal portions of the inner and outer lobes of the left first maxilla. × 38.
15. —— —— Ventral view of the right maxillipede. × 19.
16. —— *phosphorea*, Harger. Dorsal view of the cephalon.
17. —— —— Dorsal view of the right antennule. × 38.
18. —— —— Dorsal view of the left antenna. × 21·5.

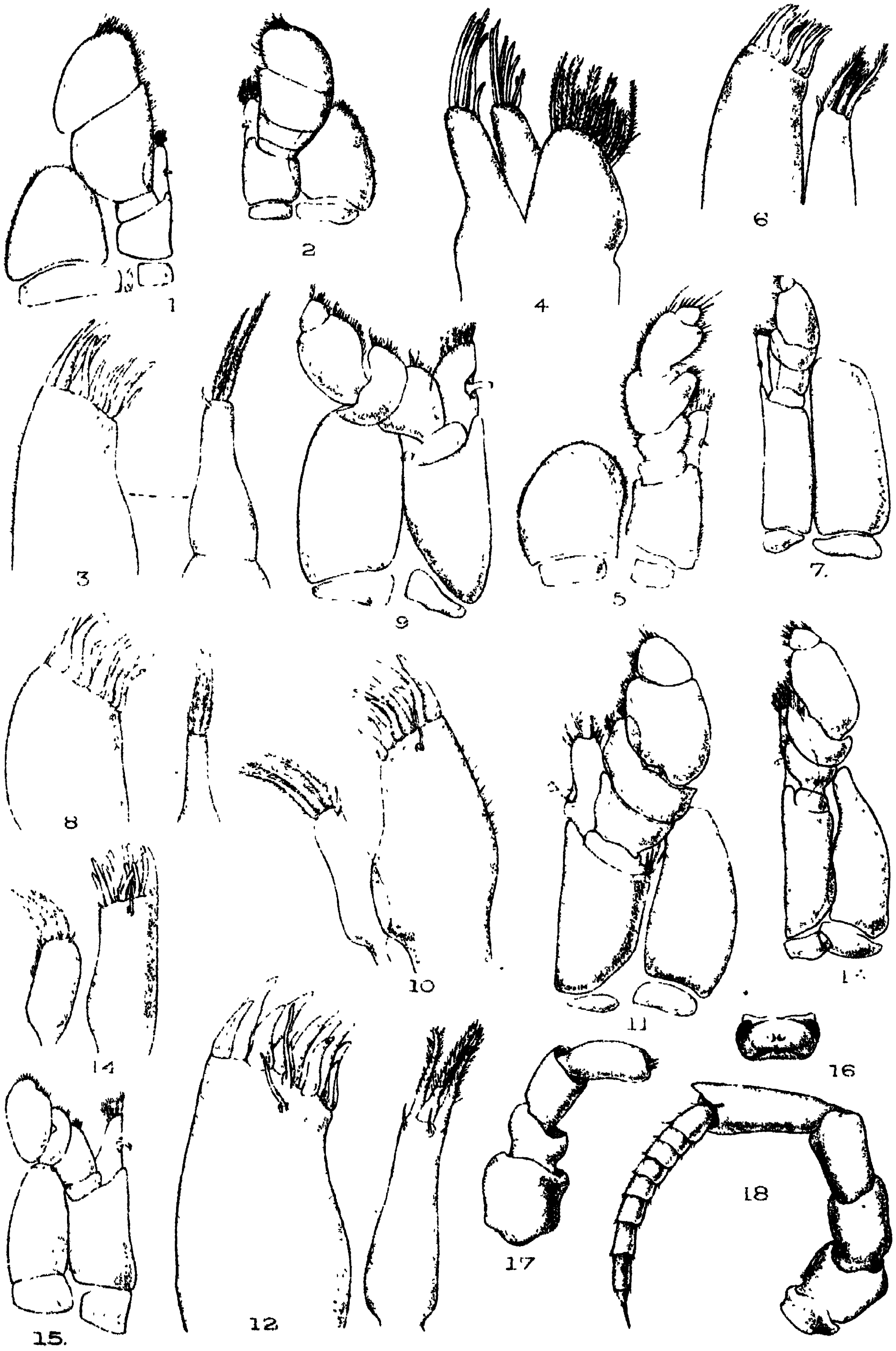
PLATE 8.

Fig. 19. *Idotea phosphorea*, Harger. Ventral view of the terminal portions of the inner and outer lobes of the left first maxilla. × 78.
20. —— —— Ventral view of the left maxillipede. × 38.
21. —— —— Dorsal view of the lateral portions of the mesosomatic segments, showing the coxal plates.
22. —— —— Dorsal view of the metasome. × 8·5.
23. —— —— Left uropod × 10.
24. *Paridotea ungulata* (Pallas). Ventral view of the terminal portions of the inner and outer lobes of the right first maxilla. × 38.
25. —— —— Ventral view of the right maxillipede. × 9·5.
26. —— *reticulata*, Barnard. Ventral view of the terminal portions of the inner and outer lobes of the left first maxilla. × 38.
27. —— —— Ventral view of the left maxillipede. × 9·5.
28. —— *rubra*, Barnard. Ventral view of the terminal portions of the inner and outer lobes of the left first maxilla. × 38.
29. —— —— Ventral view of the left maxillipede. × 12.
30. —— *fucicola*, Barnard. Ventral view of the terminal portions of the inner and outer lobes of the first maxilla. × 24.
31. —— —— Ventral view of the left maxillipede. × 24.
32. *Euidotea peronii* (Milne-Edwards). Ventral view of the terminal portions of the inner and outer lobes of the right first maxilla. × 38.
33. —— —— Ventral view of the right maxillipede. × 14.
34. *Erichsonella attenuata* (Harger). Ventral view of the terminal portions of the inner and outer lobes of the right first maxilla. × 75.

PLATE 9.

Fig. 35. *Erichsonella attenuata* (Harger). Ventral view of the right maxillipede. × 38.
36. *Synidotea hirtipes* (Milne-Edwards). Ventral view of the terminal portions of the inner and outer lobes of the right first maxilla. × 38.
37. —— —— Ventral view of the left maxillipede. × 16.
38. —— *pallida*, Benedict. Ventral view of the terminal portions of the inner and outer lobes of the right first maxilla. × 38.
39. —— —— Ventral view of the right maxillipede. × 18.
40. —— *nebulosa*, Benedict. Ventral view of the terminal portions of the inner and outer lobes of the left first maxilla. × 38.
41. —— —— Ventral view of the left maxillipede. × 19.
42. —— *angulata*, Benedict. Ventral view of the terminal portions of the inner and outer lobes of the right first maxilla. × 38.

Collinge. Journ. Linn. Soc. Zool. Vol. ~~XXXIII Pl. 7.~~



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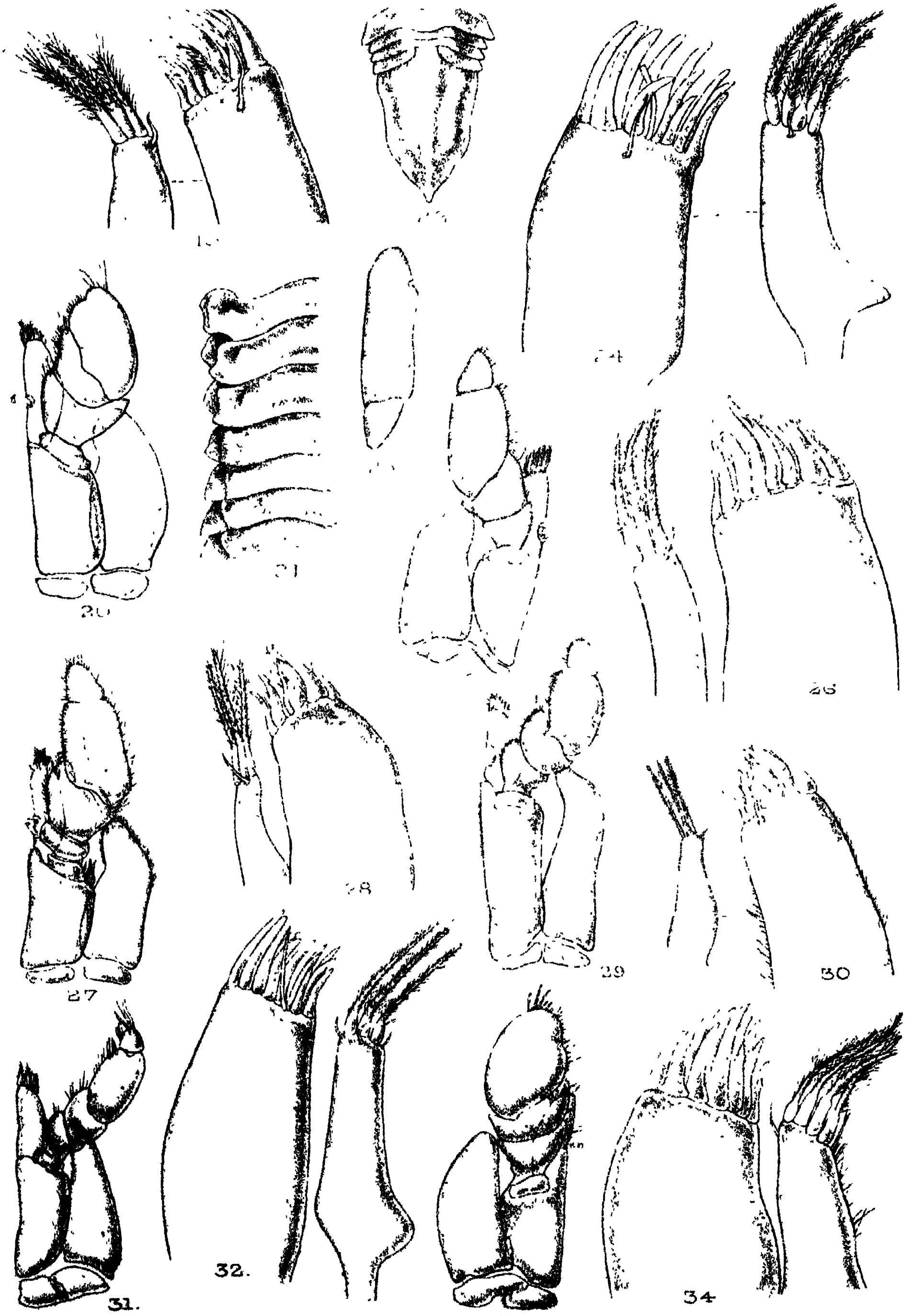
ORAL APPENDAGES OF ISOPODA.



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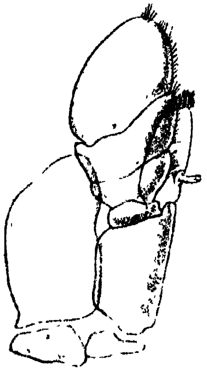

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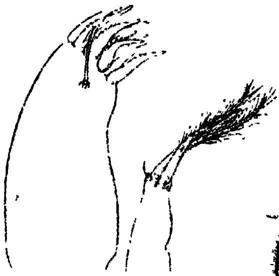

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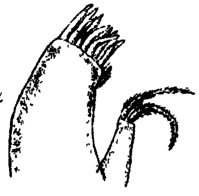

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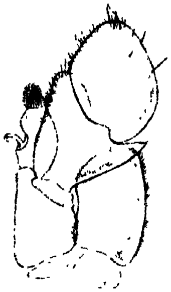

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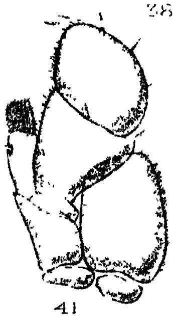

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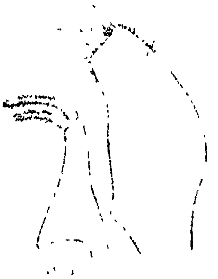

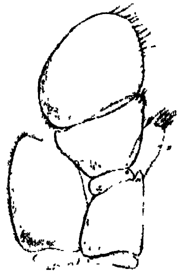

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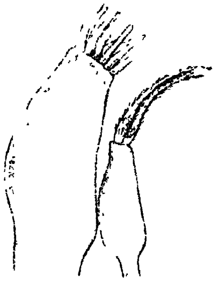

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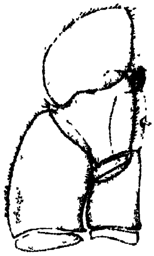

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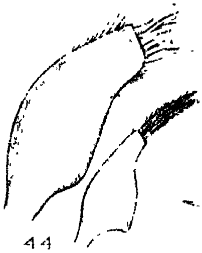

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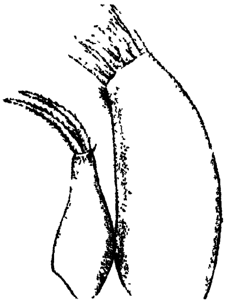

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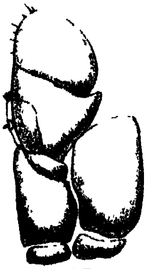

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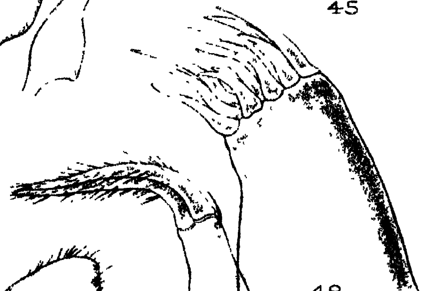

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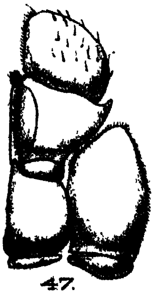

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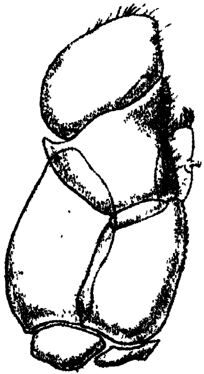

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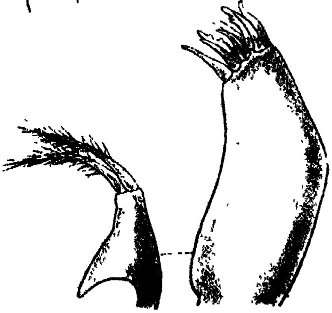

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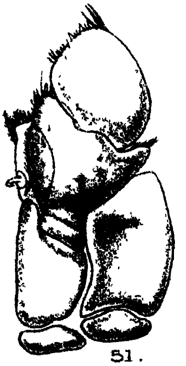

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ORAL APPENDAGES OF ISOPODA.

Fig. 43. *Synidotea angulata*, Benedict. Ventral view of the left maxillipede. × 12.

44. —— *marmorata* (Packard). Ventral view of the terminal portions of the inner and outer lobes of the right first maxilla. × 38.

45. —— —— Ventral view of the right maxillipede. × 19.

46. —— *bicuspida* (Owen) Ventral view of the terminal portions of the inner and outer lobes of the left first maxilla. × 26.

47. —— —— Ventral view of the left maxillipede. × 10.

48. —— *nodulosa* (Kroyer) Ventral view of the terminal portions of the inner and outer lobes of the left first maxilla. × 100.

49. —— —— Ventral view of the right maxillipede. × 38.

50. —— *lævis*, Benedict. Ventral view of the terminal portions of the inner and outer lobes of the left first maxilla. × 38.

51. —— —— Ventral view of the left maxillipede. × 19.

The author desires to thank the Carnegie Trust for the Universities of Scotland for a grant to defray artists' charges.

SPOLIA RUNIANA.—III. The Distribution of certain Diatoms and Copepoda, throughout the year, in the Irish Sea. By W. A. HERDMAN, F.R.S., F.L.S., Professor of Zoology in the University of Liverpool.

(With 21 Text-figures.)

[Read 1st November, 1917.]

Reprinted from Journ. Linn. Soc., Bot. vol xliv. (1918), pp. 173–204.

PART of the work [*] of the yacht 'Runa' for some years previous to 1914 consisted in taking periodic samples of the marine plankton at various localities around Port Erin, at the south end of the Isle of Man, during the two most interesting times in the annual cycle—viz., spring (March–April) and autumn (July–September). During the remaining months, when the yacht was not in commission, plankton gatherings in Port Erin bay were taken with great regularity at the rate of six in the week, three at a time on two occasions per week, two of the three hauls being horizontal and the third vertical. This systematic plankton survey has been continued for fully 10 years (1907–1917 inclusive), and over 5000 [†] samples have been collected and examined. The general results of this intensive study of the plankton of a central area of the Irish Sea have been given in a series of reports [‡] drawn up in collaboration with Mr. Andrew Scott, A.L.S., and others, and published by the Lancashire and Western Sea-Fisheries Committee; but the material and statistics collected still contain much information which has not yet been made use of. It is proposed in the present communication [§] to deal with the records of the occurrence throughout the year in our district of a few of the most abundant of the Diatoms and the Copepoda which make up the bulk of the phytoplankton and of the zooplankton respectively at those periods of the year when they are most abundant. At the time of the spring maximum (usually in April or May) a small silk tow-net hauled for about 15 minutes through about half-a-mile of the surface water of the Irish Sea will usually catch some millions of individual Diatoms (up to a couple of hundred millions [||] on occasions), constituting probably, on the average, some 999,999 out of each million of organisms in the gathering [¶]. This is almost a pure sample of Diatoms—a "monotonic phytoplankton." Similarly, when the zooplankton is at its height in late summer (usually September) the same net may contain almost a pure gathering of Copepoda numbering some tens to hundreds of thousands of individuals (up to 214,000), and making up perhaps 999 out of every thousand organisms present—a "monotonic zooplankton." But we may still regard the gathering as a zooplankton if over 50 per cent. of the organisms are animals—on account of their greater bulk.

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[*] For Parts I. and II. of "Spolia Runiana" see Journ. Linn. Soc., Zool. xxxii. p. 163 (1913), and p. 269 (1914).

[†] More precisely 5116, to the end of 1916.

[‡] Trans. Biol. Soc. Liverpool, xxii. (1908) to xxxi. (1917).

[§] I wish to acknowledge, with thanks, the help I have received in the preparation of these plankton records from Mr. Andrew Scott, A.L.S., and from my secretary, Miss H. M. Lewis, B.A. Mr. Scott took for me the excellent photo-micrographs of the plankton from which most of the illustrations have been reproduced.

[||] Estimated by counting measured samples.

[¶] The average of a number of cases where smaller, but still very large, hauls of Diatoms were taken is—Diatoms—about 99 per cent. of the total organisms present.

Moreover, these very abundant Diatoms and Copepoda belong in each case to very few species, so that one can select about half-a-dozen species of Copepoda which constitute by far the greater part of the summer zooplankton, and about the same number of Diatoms which similarly make up the bulk of the spring phytoplankton. These few species, belonging to these two very widely separated groups, thus come to be the most significant organisms in relation to the annual metabolic cycle of our seas and the food-supply from our coastal fisheries. Consequently it is of both scientific and economic importance to obtain such data as seem possible from our long series of observations, extending over a decade, as to the occurrence of these dominant factors in the plankton. No doubt there are exceptional years with unusual occurrences which will have a disturbing effect, but the ten or eleven years' results ought to give us an average of some value.

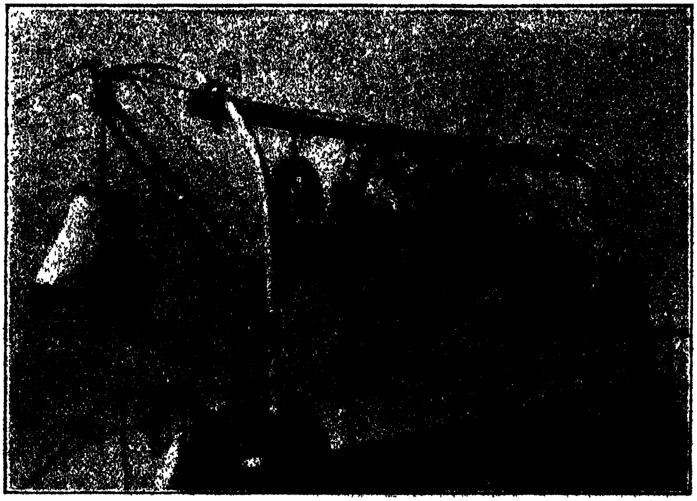

FIG. 1.—"Hensen," "Nansen," "Funnel" and other plankton nets drying after use on the yacht.

We have endeavoured, in our work from the yacht, as the result of many experiments, to make use of a standard net in a constant manner so that the hauls should be approximately comparable. Our two horizontal tow-nets of fine-meshed miller's silk (No. 20 and No. [illegible]) measure 35 cm. (about 14 inches) in diameter at the mouth, and are in our weekly gatherings throughout the year hauled through a definite course in the open water of Port Erin bay. The two together ("coarse" and "fine" nets) constitute a "standard haul." The gatherings taken outside the bay during the periods of the vernal and autumnal plankton maxima were made with the same nets as in the bay, at fixed "stations" respectively three and five (and on a few occasions ten) miles from land *.

In addition to these standard hauls many others were taken with special nets, such as the closing "Petersen-Hensen" and "Nansen," the "shear-net" and "funnel-nets," usually at depths of 5 to 30 fathoms, and on occasions down to 60 fathoms out in the deep central valley between the Isle of Man and Ireland. Figure 1 gives a general view of the various nets used on one of our plankton cruises. Temperatures, surface and deeper, weather observations and water-samples were also taken systematically †.

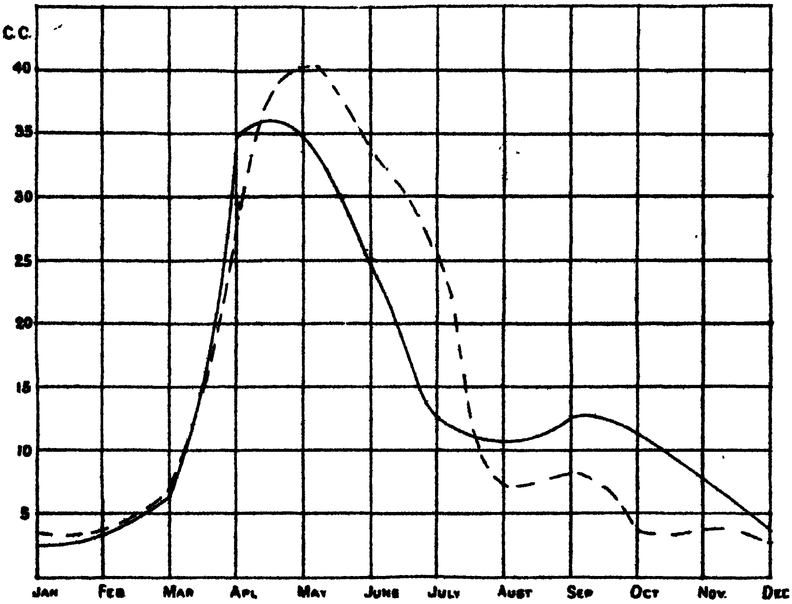

Fig. 2.—Typical Irish Sea plankton curves for the years 1913 (dotted line) and 1914 (whole line).

The plankton gatherings when taken are at once treated with formol to kill and fix the organisms and prevent further changes. They are then placed (at the Port Erin Biological Station) in graduated cylinders, and after some hours, when the material has fallen to the bottom and the superjacent fluid is clear, the quantity of plankton in cubic centimetres is recorded. The fixed plankton is then concentrated and preserved in

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* Determined by cross-bearings, and by distance run calculated from the engines.

† For further particulars as to methods, see the earlier reports published by the Lancashire and Western Sea-Fisheries Committee.

5 per cent. formol, and is re-measured it may be weeks later when submitted to detailed examination. It is this last more accurate measurement that has been made use of for calculations and curves. The first estimation of the volume is only taken in case some accident happens later; but we have been very fortunate in that respect: we have only lost about 10 gatherings in the 10 years out of over 5000 samples. Figure 2 shows typical plankton curves for the years 1913 (dotted line) and 1914, taken from the recorded monthly averages of the plankton hauls. As an example of the height to which individual hauls may rise in spring, I may quote from our records of this year that on April 18th, 1917, the standard haul measured 165 c.c., and on April 19th 150 c.c., and consisted mainly of *Chætoceras*.

Our confidence that these samples are adequate and representative receives support from the fact that the same organisms are recorded in much the same quantities year after year, and that practically no new forms turn up. Mr. Andrew Scott, A.L.S., who has made a detailed microscopic examination of all the material for the purpose of determining the species, has met with none new to science. Some rare species previously unknown in British seas, such as the Norwegian Copepod *Microcalanus pusillus*, Sars, which appeared first in our deeper nets in the summer of 1907, and the Indo-Pacific Diatom *Biddulphia sinensis*, Grev., have occurred; but throughout the series of over 5000 gatherings, extending over nearly every week of 10 years, no species actually new to science has been determined from the macroplankton. The various new Copepoda which have been described from time to time from our work at Port Erin have all been bottom-living forms obtained by dredging. This is, so far, a satisfactory result of our work, as it seems to indicate that probably all the pelagic species of Copepoda in our sea are now known. It is not the rare species that are of most interest. They may have an interest of their own—morphological or distributional—but for my present purpose it is the common species that are of most importance, those species which by their abundance in nature play their part in providing fish-food for man or in affecting the public health either by keeping the sea clean or by causing plagues.

For the purpose then of arriving at some conclusion as to the distribution throughout the year of these really significant organisms, I have picked out from our records the following six species of Copepoda as being undoubtedly the most abundant and economically the most important representatives of that section of the plankton:—*Oithona helgolandica* (= *similis*), *Pseudocalanus elongatus*, *Acartia clausi*, *Temora longicornis*, *Paracalanus parvus*, and *Calanus finmarchicus*. These are all cases of genera where there is only one species in our seas (e. g., *Calanus*) or only one common species (e. g., *Oithona*), so that we are dealing with half-a-dozen very distinct forms, and there can be no doubt as to what is in question even if the genus only is referred to.

When we turn to the Diatoms the case is rather different. There several of the more prominent genera are represented by a number of common species, and moreover some of the species are closely related, and variable, so that doubts may arise as to the exact identifications, and authorities may differ as to the relative proportions in which certain species or varieties of, say, *Chætoceras* or *Biddulphia* are present in the plankton. Under these circumstances I have considered it will best serve my purpose, which is a general and economic rather than a detailed speciographic one, if I deal with generic titles only, grouping together for example all the species of *Chætoceras* that may occur under that one name. I have chosen the following genera as being the most important representatives of the Diatoms in our plankton :—*Biddulphia*, *Chætoceras*, *Coscinodiscus*, *Rhizosolenia*, *Thalassiosira*, *Guinardia*, and *Lauderia*. In some of these genera (e. g., *Guinardia* and *Lauderia*) as in the case of the Copepoda there is only one possible species in question, in *Biddulphia* it is in most cases only the species *B. mobiliensis*, but in others (e. g., *Chætoceras*, *Coscinodiscus*, and *Rhizosolenia*) there are usually several allied species occurring together in profusion in any large gathering of the genus.

I may add that our commonest species in the Irish Sea off Port Erin are not necessarily those that are most abundant in other seas of North-West Europe. For example, in the Baltic near Kiel, according to Lohmann, the most abundant Diatom is *Skeletonema costatum*, a comparatively rare form in our plankton, and George Murray similarly found that to be the commonest form he had met with in a plankton survey of some of the more sheltered lochs of the West of Scotland. It is, however, one of the minuter forms which readily escapes notice, and may to a considerable extent pass through the meshes of the net.

Then again, in July 1911, in Upper Loch Torridon, on the West Coast of Scotland, I got a haul of 334,000,000 *Nitzschia delicatissima*, which is rare with us in the Irish Sea, but is apparently more abundant at Plymouth.

I think it probable, however, that our Port Erin results will be found to hold good for the more open sea-water of high salinity [*] around the British Isles. A valuable paper which appeared recently on the Plankton of Plymouth Sound, by Dr. Marie V. Lebour [†], while dealing mainly with the more minute Protozoa and Protophyta which escape the tow-net and can only be obtained by centrifuging samples of water, gave also some records of the occurrence of some of the larger forms which enables a comparison to be made between the plankton conditions in the English Channel and in the northern part of the Irish Sea.

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[*] The salinity off Port Erin averages about 34·2 per mille. Its range for April, May, and June in the year when we took the most complete series of observations is from 34·02 to 34·4 per mille.

[†] Journ. Mar. Biol. Assoc. vol. xi. 2 (1917), p. 133.

There are certain differences in detail. For example, the total Diatom curve at Plymouth has three maxima or crests, in April, August, and October. At Port Erin the curve has only two crests, a much greater maximum in spring and a variable and smaller one in autumn, while Diatoms are usually wholly absent in August.

On the other hand, there is a general agreement in regard to the distribution throughout the year of many of the more abundant organisms. For example, amongst Diatoms *Coscinodiscus* is a winter and early spring form, *Biddulphia* flourishes throughout the winter from November to April or May, *Rhizosolenia* is a summer form having its maximum in June, while *Chætoceras* and *Lauderia* have two maxima, the one in spring and the other in autumn, in the English Channel and the Irish Sea alike. Amongst Copepoda there seems to be a general agreement along with a certain amount of difference in detail which will be referred to below when discussing the species.

I may recall that in November 1910 I read a paper before this Society * in which I made a comparison between the summer (July) plankton on the West Coast of Scotland and that of the Irish Sea, showing that in some of the deep fjord-like highland sea-lochs green-coloured phytoplankton can be obtained even in the height of summer, while a zooplankton may be found living in abundance a few miles away. This, of course, would be impossible in the Irish Sea, where a zooplankton and a phytoplankton do not occur simultaneously.

DIATOMS.

The seven generic forms I have selected for consideration taken together make up nearly the whole of the Diatom plankton of the year. No other genus occurs in anything like such profusion as these. In April, for example, when the Diatoms are usually at their climax, all the remaining genera (at most 10 or 12) taken together make up only about one-thousandth, or less, of the whole. Moreover, these common Diatoms often attain their greatest profusion successively, not simultaneously, so that single genera, or it may be single species of a genus, make up on occasions the bulk of the phytoplankton. For example, in May 1916 the month's average haul of Diatoms was 7,171,789, while the average for the genus *Chætoceras* taken alone was 6,947,333, leaving only 224,456 as the average of all the rest of the Diatoms. On the last two individual hauls, taken on May 25th and 29th, the actual numbers were as follows:—

Chætoceras alone	24,094,500 ...	19,461,600
C. sociale alone	23,936,000 ...	19,396,000
All other Diatoms together...	166,300 ...	228,900

So that on these occasions, and they are examples of many, one species makes up nearly the whole of the plankton.

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* Journ. Linn. Soc., Zool. xxxii. (1913) p. 23.

The maximum on the Diatom curve ranges from March to May. In 1907 it was in March, in 1908 in May, and in 1909 in April. In some years the Diatom maximum may be divided into two parts, an earlier due mainly to *Chætoceras* and *Thalassiosira*, and a later in June due to *Rhizosolenia* and *Guinardia*. A common order of succession for the species which contribute most largely to the Diatom maxima is—*Biddulphia mobiliensis* and *Coscinodiscus radiatus* in early April, *Chætoceras debile* in late April, *Chætoceras sociale* in May, *Chætoceras teres* and *Rhizosolenia Shrubsolei* in early June, and *Rhizosolenia* (several species) and *Guinardia* in later June. The autumn Diatom maximum is constituted mainly in the Irish Sea by *Chætoceras subtile* and *Rhizosolenia semispina*. Certain species of most of the genera we are dealing with are commonly regarded as "oceanic" in the sense that they are characteristic of the open sea, although they may occasionally be carried in shore and so form a part of the coastal plankton; while other species are "neritic," having their origin and their home in coastal waters and not being found normally in the open ocean. For example, *Chætoceras densum*, *C. boreale*, *Coscinodiscus radiatus*, and *Rhizosolenia semispina* are supposed to be oceanic; while *Biddulphia mobiliensis*, *Chætoceras subtile* (and other species), *Coscinodiscus concinnus*, *Rhizosolenia setigera*, and *Lauderia borealis* are probably neritic. Other species of these genera are of doubtful position in this classification, or it may be are "panthalassic" or equally at home in both regions.

BIDDULPHIA.

This is a winter and early spring group of Diatoms, generally appearing in September or October, becoming more abundant in November and reaching a maximum in March or April. It dies off during May, and is practically absent in June, July, and August.

The species, or forms, that occur in our plankton are *Biddulphia mobiliensis* (? *B. regia*) and *B. sinensis* (fig. 3). This is one of the cases where there is some difference of opinion as to the validity of species. Whether *B. regia* is only a form of *B. mobiliensis*, and what is the exact relation of *B. sinensis* to the others, has been and may still be a matter of discussion. Specimens can be picked out that seem distinct and characteristic, but others occur in nature that are intermediate and possibly abnormal *.

B. sinensis is an exotic, oceanic form which, according to Ostenfeld, made its appearance at the mouth of the Elbe in 1893, and spread during successive years in several directions. It appeared suddenly in our plankton gatherings at Port Erin in November 1909, and has been present in abundance each year since. Ostenfeld, in 1908, when tracing its spread in the North Sea, predicted that it would soon be found in the English Channel. Miss Lebour, who has recently examined the old plankton gatherings at the Plymouth

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* See forms figured in Trans. Biol. Soc. Liverpool, xxvii. (1913) p. 210.

Laboratory, finds that as a matter of fact this form did appear in abundance in the collections of October 1909, within a month of the time when according to our records it reached Port Erin. Whether or not this species was brought accidentally by a ship from the far East, there is no doubt that it was not present in our Irish Sea plankton gatherings previous to 1909, but has been abundant since that year, and has completely adopted the habits of its English relations—appearing with *B. mobiliensis* in late autumn, persisting during the winter, reaching a maximum in spring, and dying out before summer. *Biddulphia* is generally the first Diatom to show a marked increase in early spring, and is responsible for the moderate rise in the curve which takes place in February or March.

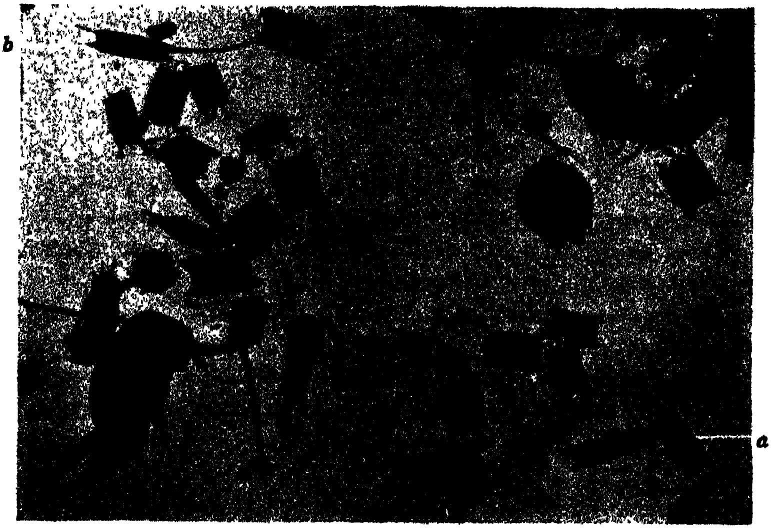

FIG. 3.—Photo-micrograph of a plankton preparation showing (*a*) *Biddulphia mobiliensis*, forma "*regia*," and (*b*) *B. sinensis*.

Our largest records of *Biddulphia* are as follows :—

From three hundred thousand to over six hundred thousand per haul on several occasions between middle of March and middle of April in 1910 and 1911, and towards end of April and beginning of May, 1916.

From three hundred thousand to over seven hundred and fifty thousand on ten occasions between November 10th and 27th, 1911, 1914, and 1915.

The highest monthly averages in the early spring months occur as follows :—

February ...	in 1907 and 1912.
March ...	in 1910, 1911, 1914, and 1915.
April ...	in 1908, 1909, 1913, and 1916.

A second, usually slighter, maximum occurs in November, when the numbers are higher than in December and January ; but on three occasions

(1911, 1914, and 1915) in our ten years the November monthly average is the highest in its year. Moreover, two of these November records, viz., 341,231 in 1911 and 406,100 in 1914, are the highest in the whole series. So *Biddulphia* may be regarded as characteristic of the late autumn (November) as well as the early spring plankton.

COSCINODISCUS.

The more abundant species that our records deal with are *Coscinodiscus concinnus*, *C. Grani*, and *C. radiatus*. They are mainly winter and spring forms, the maximum of the genus occurring always in our experience in either March or April. *Coscinodiscus* (fig. 4) agrees very closely with *Biddulphia* in its distribution throughout the year, beginning in late autumn, maintaining its position throughout the winter, increasing in January or February, and then more rapidly in March and April, and dying away before the height of the summer; but it sometimes continues to be present in small quantities further into the summer months than is the case with *Biddulphia*.

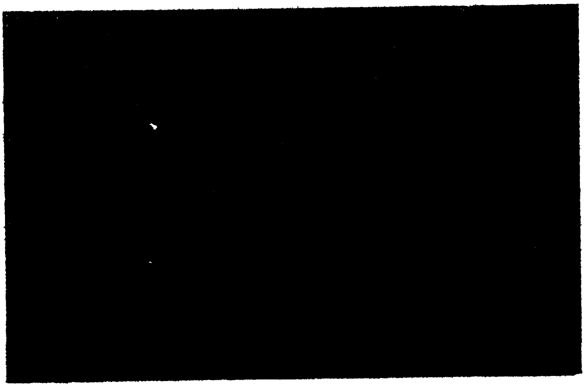

FIG. 4.—Photo-micrograph of an early spring phytoplankton consisting mainly of *Coscinodiscus* and *Biddulphia*.

The presence of *Coscinodiscus* in quantity in the spring plankton is easily seen through a glass jar with the unaided eye, as the little rounded drum-like cells give a characteristic granular appearance to the gathering.

Our largest records of *Coscinodiscus* are :—

From four to five hundred thousand per haul on several occasions between middle of March and middle of April, 1911, 1912, 1913, 1915, and 1916.

About nine hundred thousand on several occasions at end of April 1914.

From one million to close on five millions on two occasions in middle of April 1915.

So *Coscinodiscus* may outrival its companion form *Biddulphia* at the time of the vernal maximum, but does not attain to such high numbers in late autumn. The October and November monthly averages never, in our series of years, come anywhere near the averages for March and April.

Both *Biddulphia* and *Coscinodiscus* seem to be slightly later in their maxima in the Irish Sea than in the English Channel, judging from the Plymouth records.

In the years 1907 to 1912, inclusive, the highest monthly averages (March and April) for *Coscinodiscus* run in general about 100,000. In 1913 and 1916 they are close on 200,000, in 1914 over 300,000, and in 1915 there is a sudden jump, in April, to over 840,000. The other months of that year do not show unusually high numbers.

CHÆTOCERAS.

The chief species of this genus in our Irish Sea plankton are *Chætoceras boreale*, *C. contortum*, *C. criophilum*, *C. debile*, *C. decipiens* (fig. 6), *C. densum*,

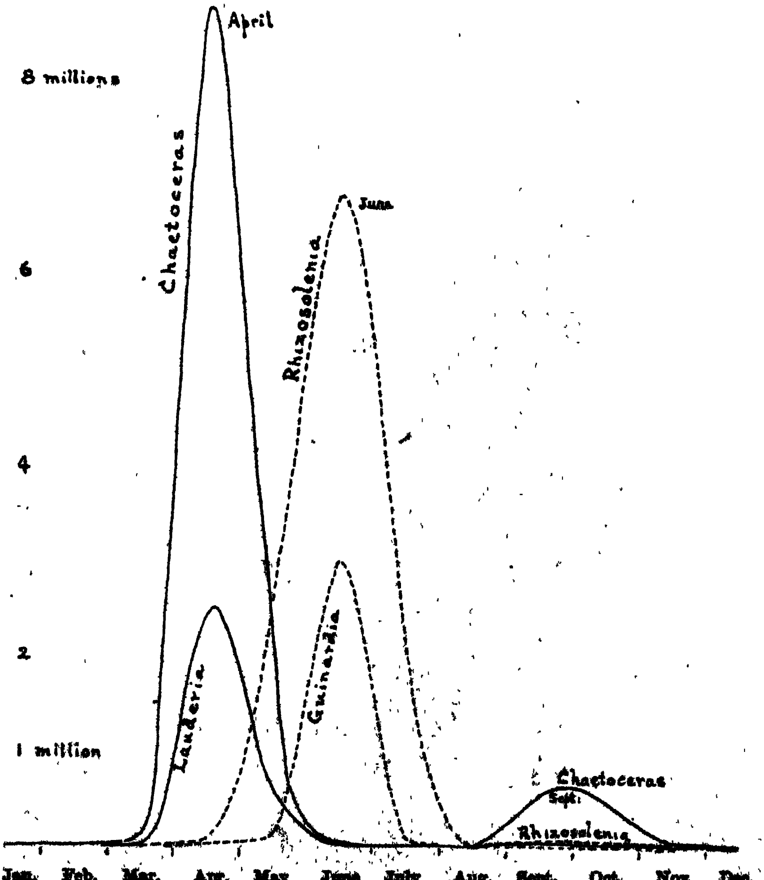

FIG. 5.—Curves of the more important Diatoms of the April and June maxima.

C. diadema, *C. sociale*, and *C. teres*. Of these, *C. boreale*, *C. criophilum*, and *C. decipiens* are Arctic oceanic forms, *C. densum* is a temperate oceanic or

Atlantic species, and all the rest may be classified as temperate neritic. Some of these (*C. criophilum*, *C. debile*, *C. decipiens*, *C. sociale*, and *C. teres*) are spring forms with a maximum in April or May, while *C. boreale* and *C. densum* are autumn species having their maxima in September or October. Consequently the genus is well represented throughout a considerable part of the year, and the numbers are very high in April and May, and sometimes also in September and October (see curve, fig. 5). A few of our highest records for the genus, giving the nearest million in each case, are :—151 millions on May 4th, 1914, 95 millions on April 29th, 1912, 68 millions on May 16th, 1911, 49 millions on April 22nd, 1910, and 44 millions on May 19th, 1911. The highest record we have for the autumn species is 30 millions on September 26th, 1912. On May 16th, 1911, *C. debile* contributed 30 millions and *C. sociale* 12 millions to the total in the haul ; and on May 4th, 1914, *C. debile* gave 148 out of the 151 millions present. If we examine the records of the separate species for the year 1914 as an example, we find that *C. contortum* has an average of 62,700 per haul in May, *C. debile* an average of 867,878 in April and 18,972,800 in May (the record), *C. decipiens* an average of 821,311 in April and 321,050 in May, *C. sociale* an average of 1,229,500 in May, *C. teres* an average of 577,867 in April ; while of the autumn species *C. boreale* has an average of 53,200 in September and 54,644 in October, and *C. densum* has 151,120 in September and 100,624 in October. *C. debile* and *C. decipiens* were also very abundant that October.

FIG. 6.—*Chætoceras decipiens*, showing the active winter growth. From a photo-micrograph by A. Scott.

The highest monthly averages for *Chætoceras* fall as follows during our ten years :—

March	...	in 1907.
April	...	in 1909, 1910, and 1912.
May	...	in 1908, 1911, 1913, 1914, 1915, and 1916.

The highest average is nearly 23 millions, in May 1911. None of the September and October averages run as high as those in spring, and only two reach millions, viz., 3,956,047 in October 1911, and 7,702,658 in September 1912. The years 1911 and 1912 had high numbers of *Chætoceras* throughout many of the months *. There are no months in the ten years when *Chætoceras* was totally unrepresented; but July and August show the lowest averages—the lowest of all being only six individual cells in August 1907.

LAUDERIA.

We have only the one species, *Lauderia borealis*, Gran (fig. 7), in our records. It is a late spring or early summer form, occurring generally from March or April to June or July, with a later, smaller, occurrence in autumn. It is sometimes present in large quantities, *e. g.*, 20,064,000 on April 22nd, 1910; 12½ millions on April 29th, 1912; 3,600,000 on May 4th, 1914. The maximum is towards the end of April or beginning of May, when *Lauderia* helps, along with *Chætoceras*, to form the main crest on the vernal Diatom curve (see fig. 5).

FIG. 7.—Photo-micrograph showing a chain of *Lauderia borealis*.

THALASSIOSIRA.

The only species of this genus that are of any importance in our records are *T. gravida*, Cleve, and *T. Nordenskioldi*, Cleve (fig. 8). Apparently *T. gravida* is the only one common at Plymouth, but *T. Nordenskioldi*, along with *Chætoceras contortum* and *C. debile*, helped to constitute the vernal maximum at Port Erin in 1907, and has been still more abundant on several occasions since. *T. Nordenskioldi* is in the main a neritic, arctic or Scandinavian species, and probably its occasional occurrences in quantity are to be regarded as invasions of some arctic water and northern plankton into our British seas. In April 1917, it was abundant at Port Erin along with *Chætoceras teres*, *C. debile*, and *C. decipiens*.

All our high records (over a million per haul) for *Thalassiosira* lie between late in April and late in May, and the two highest are six millions on April 29th, 1912, and six and a half millions on May 16th, 1913. Other high records have occurred during these same months, in 1910, 1911, 1912, 1913, 1914, 1915, and 1916.

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* The largest hauls of Diatoms as a whole, all species taken together, were in May of 1912 and 1913 (see Table on p. 133).

The highest monthly averages for *Thalassiosira* are 721,000 in April 1912, 898,000 in May 1913, and 976,000 in May 1915. The genus is totally absent from our records throughout the ten years in December, January, and February, and again in July and August, and is very poorly represented in several other months. In fact, it is only really abundant in April and May and not always then. In this distribution over the months of the decade this genus forms a marked contrast with *Chætoceras*, which is so constantly present.

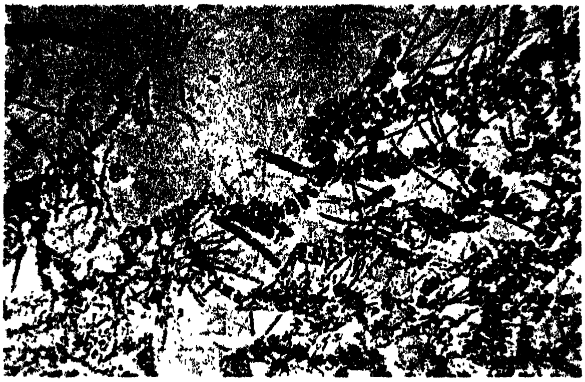

FIG. 8.—Photo-micrograph of a phytoplankton consisting mainly of *Thalassiosira Nordenskioldi.*

RHIZOSOLENIA.

The species that occur most abundantly in our records are *Rhizosolenia semispina*, *R. Shrubsolei*, *R. Stolterfothi* and, less abundantly, *R. setigera* and *R. alata* (rarely). The two last named are temperate Atlantic forms, and *R. semispina* is a typically arctic oceanic species.

They are all summer or autumn species, the genus being often quite unrepresented in certain of the winter months. It usually begins to appear in the nets in February and reaches its maximum in June. The numbers are sometimes enormous, giving the water in a glass jar a characteristic silky or fibrous appearance and causing the June crest that is usually present as a distinct elevation on the Diatom curve (see fig. 5, p. 182).

The most abundant species in the Irish Sea is *Rhizosolenia Shrubsolei*—at Plymouth it is *R. Stolterfothi* ; but *R. semispina* (fig. 9) is sometimes present in abundance at Port Erin in autumn, causing a second crest or maximum in September or October. In September 1907, thirteen millions and sixteen millions of this species were taken in two hauls of the surface-net at Station III. (three miles off Port Erin), while the following year, at the same time and locality, it was almost absent.

We have had much larger numbers, of *R. Shrubsolei*, in June; and amongst our largest records of the genus taken as a whole are:—184 millions on May 30th, 178 millions on June 3rd. 59 millions on June 8th, 43 millions on June 13th, all in 1912, and 17 millions on June 21st, 1915.

FIG. 9.—Photo-micrograph of a phytoplankton consisting mainly of *Rhizosolenia semispina*.

The highest monthly average is in June in all of our years except 1907 when it was in May, and 1913 and 1916 when it was in July. The greatest average recorded is over 40 millions in June 1912.

The autumn records are very irregular and sometimes show no rise whatever. Even when present it is slight compared with the June maximum (see fig. 5, p. 182). The highest monthly average in autumn is 117,122, in September 1912.

GUINARDIA.

Only the one species, *Guinardia flaccida*, occurs in our records (fig. 10). It is a summer form occurring mainly between April and July, with the maximum almost invariably in June. Our largest records are 22,800,000 on June 3rd, 1912; 18,000,000 on May 30th, 1912; and 8,773,000 on June 11th, 1910. We have several records of over 7,000,000 early in June, one of over two millions on July 8th, 1913, and one of over a million as late as July 16th, 1916.

Guinardia, when present, makes up along with *Rhizosolenia* the June elevation, which is sometimes so marked towards the end of the vernal Diatom maximum. This last summer (1917) it was unusually late, showing a maximum of five millions on 23rd July, along with one million of *Rhizosolenia*.

The highest monthly averages are all in June with the exception of 1916, when it was in July. The greatest recorded average is close on six millions for June 1912. The lesser, secondary, increase in autumn has its highest point in September—the greatest recorded monthly average being 10,967 for September 1912. It is interesting to notice that according to Pavillard *Guinardia flaccida* is abundant in the Gulf of Lyons as late as October.

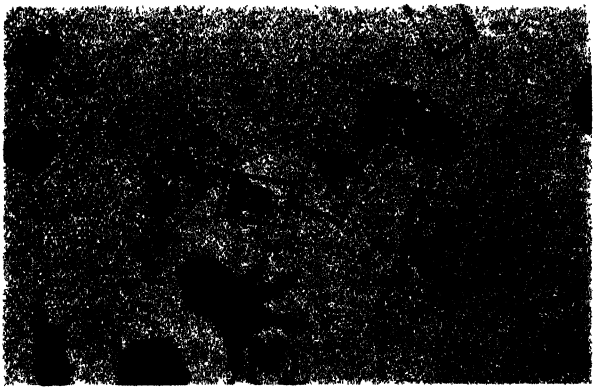

FIG. 10.—*Guinardia flaccida*, from a photo-micrograph by A. Scott.

TABLE

showing the monthly averages of the selected Diatoms throughout a year.

1912.	*Biddulphia.*	*Chætoceras.*	*Coscinodiscus.*	*Rhizosolenia.*	*Thalassiosira.*	*Guinardia.*	*Lauderia.*
Jan.	24,920	7,342	9,877	22	0	257	189
Feb. ..	36,885	10,301	10,034	12	0	105	0
Mar. ..	21,176	3,977,292	95,446	525	25	162	337
Apr. ..	21,869	18,365,750	100,619	36,464	721,338	3,158	1,622,478
May ..	1,072	2,844,861	14,586	22,008,744	41,033	2,789,433	170,878
June ..	0	67,543	0	40,833,771	0	5,919,429	0
July ..	0	39,527	56	1,228	0	158	0
Aug. ..	11	694,961	0	13	0	0	0
Sept. ..	4,131	7,702,658	1,677	117,122	3,978	10,967	8,944
Oct.	5,827	214,421	11,914	820	57	2,176	29
Nov. ..	25,714	9,476	5,436	0	0	21	0
Dec. ..	8,059	1,106	1,573	0	0	141	0

The above table shows very clearly how these important genera reach their maxima at different times, and how, for example, *Chætoceras* in spring (April) gives place to *Rhizosolenia* and *Guinardia* in early summer (May and June). Curves can be drawn mentally from a glance at the columns of figures which will demonstrate the waxing and waning of the several types.

The following table showing the largest hauls of total Diatoms and of total Copepoda in each of the ten years brings out well how greatly the Diatoms outnumber the Copepoda—in some cases in the proportion of about a thousand to one.

	Diatoms.		Copepoda.	
	Largest haul.	Date.	Largest haul.	Date.
1907	698,350	April 6th	28,900	Aug. 17th
1908	5,746,300	May 28th	68,015	Sept. 14th
1909	10,358,300	April 22nd	71,010	Oct. 18th
1910	70,128,400	April 22nd	119,650	Sept. 19th
1911	69,982,500	May 16th	248,045	July 18th
1912	202,993,600	May 30th	223,789[*]	May 20th
1913	205,814,700	May 16th	118,660	July 21st
1914	155,288,000	May 4th	217,571	Nov. 9th
1915	18,893,300	June 15th	117,340	Aug. 2nd
1916	24,260,800	May 25th	118,524	Sept. 25th
1917	64,339,250	May 3rd	147,706	July 19th

The relatively high records for Diatoms in 1912 and 1913 are due in the former case to the usual June maximum of *Rhizosolenia* and *Guinardia*, and in the latter case to a quite exceptional invasion of *Asterionella japonica*—the only occasion in our records when this genus has been abundant in the Irish Sea. We regard it as quite a rare form here. It is exceedingly abundant to the south of Iceland (Ove Paulsen) and also in the Gulf of Lyons (Pavillard).

COPEPODA.

The following table shows the total numbers recorded of our six important species of Copepoda in the years 1909 and 1910:—

	1910.	1909.
Oithona helgolandica ...	872,678	465,066
Pseudocalanus elongatus	368,326	309,973
Acartia clausi ...	340,631	63,373
Paracalanus parvus ...	217,633	54,120
Temora longicornis ...	147,043	62,659
Calanus finmarchicus ...	15,418	21,412

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[*] An exceptionally large haul at such an early date—due apparently to several moderately large swarms of different Copepoda occurring together, viz., *Calanus*, *Pseudocalanus*, *Temora*, and *Acartia*.

The actual detailed numbers are of no importance except as indications of the relative abundance of the species. It is clear that *Oithona* and *Pseudocalanus* (in 1909) far outnumber the others. *Acartia* shows a notable increase in 1910.

The Copepoda as a whole are a summer and autumn group, all the crests of their annual curves being found between May and October. Figure 11 shows curves of occurrence of the five most abundant of the above-named species for the year 1912, which may be regarded as typical. Curves of *Calanus* are shown separately in figure 12. The remaining one of our six selected species, *Calanus finmarchicus*, although much the largest individually and probably one of the most important from the fisheries point of view, only occasionally occurs in very large quantities in the Irish Sea, and its total numbers in a year are much below those of the other species, as the following table shows.

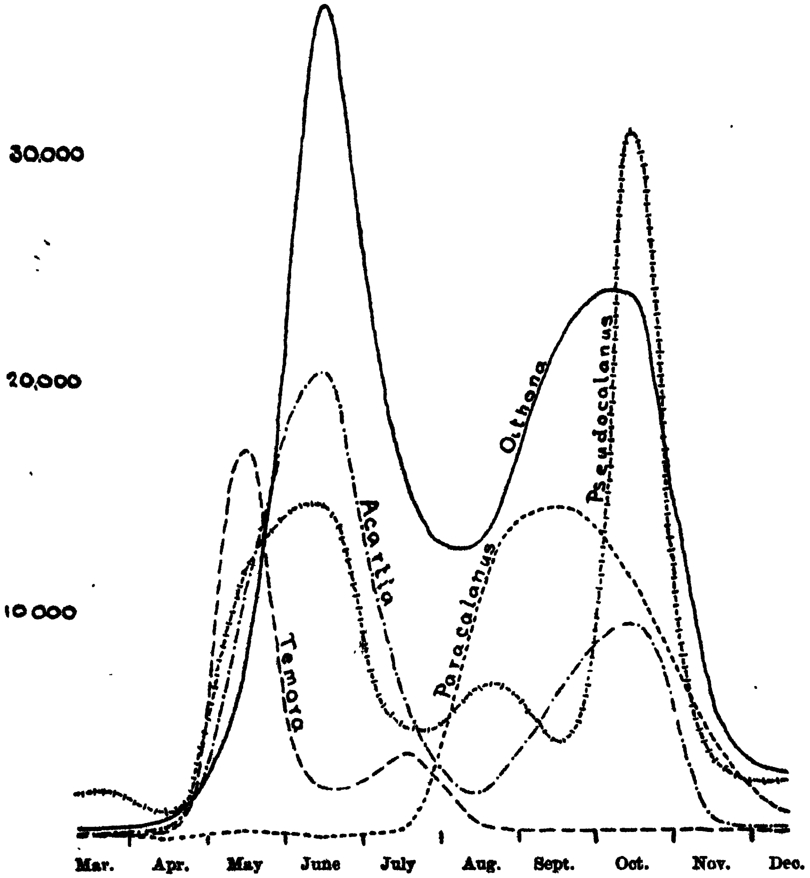

FIG. 11.—Curves of five most abundant Copepoda at Port Erin in 1912.

TABLE *showing the total numbers of the selected Copepoda recorded in the ten years.*

	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	Totals and averages over the 10 years.
No. of hauls	77	93	112	102	107	98	95	97	101	96	978
Oithona	269,775	281,634	465,066	872,678	1,155,108	1,055,213	997,565	1,189,945	865,239	839,154	7,991,377
Average per haul ..	3,503	3,028	4,152	8,556	10,795	10,767	10,501	12,267	8,567	8,741	8,171
Pseudocalanus	113,337	177,592	309,973	386,326	365,983	643,466	500,650	487,383	788,174	679,259	4,452,143
Average per haul ..	1,472	1,909	2,768	3,788	3,420	6,566	5,270	5,025	7,804	7,076	4,583
Acartia	52,211	113,923	63,373	340,631	323,633	450,778	401,305	236,985	309,110	222,729	2,514,678
Average per haul ..	678	1,225	566	3,340	3,025	4,600	4,224	2,443	3,060	2,320	2,571
Paracalanus	25,787	91,147	54,120	217,633	351,088	363,881	196,364	568,699	119,197	138,438	2,126,354
Average per haul ..	335	980	483	2,134	3,281	3,713	2,067	5,863	1,180	1,443	2,276
Temora	104,093	20,495	62,659	147,043	106,359	210,542	144,624	146,707	118,218	146,174	1,206,914
Average per haul ..	1,350	220	559	1,442	994	2,148	1,522	1,512	1,170	1,523	1,234
Calanus	21,352	19,646	21,412	15,481	5,843	79,429	23,183	42,494	13,119	18,031	259,990
Average per haul ..	277	211	191	152	55	810	244	438	130	188	266

CALANUS.

Calanus finmarchicus (Gunner)* is present throughout the year in the Irish Sea, and may be taken in small quantities at almost any time and in larger numbers on different occasions in different years. In 1907 it was fairly abundant (a few thousands in a haul) in April, and again at the end of July and the beginning of August, and in October. In 1908, on the other hand, the thousands per haul were not reached until later in the year, and the numbers remained relatively high from September to December (2,850 on December 23rd). In 1909, in addition to occasional thousands in May, June, July, and October, we have evidence of an unusually large swarm that entered the bay on July 17th and 19th, when hauls estimated at 20,000 each were obtained. The average for these three years shows maxima in July and October (see fig. 12).

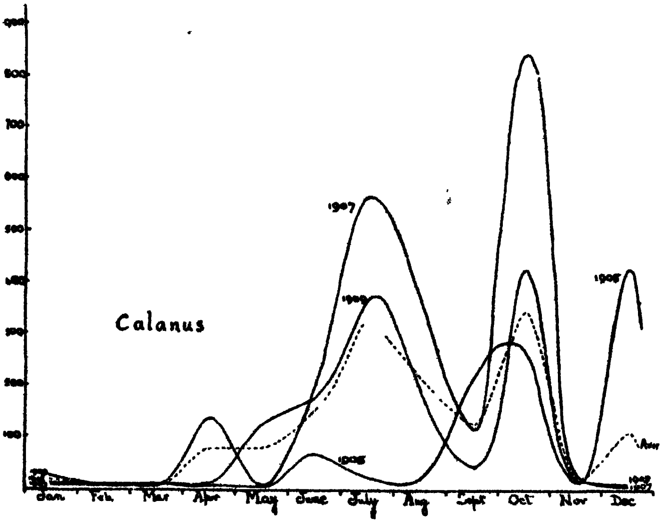

FIG. 12.—Curves of *Calanus* for three years (1907–9) at Port Erin, showing successive waves of invasion, 2 or 3 in each summer.

In 1910 there were no very large hauls, and the thousands were only reached at the end of July and the beginning of August—perhaps the most usual time for swarms to appear in the bay.

In 1911 the numbers in general were low, but two of the customary large swarms appeared in summer, one on July 4th and the other on July 18th.

In 1912 the numbers were higher again, and thousands occurred on various dates from April to October. The very high record of 50,720 was obtained on May 17th, unusually early for such a large swarm.

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* I use this older specific name as I am inclined to agree with Wolfenden, Esterly and others that the characters used in the attempt to separate "finmarchicus" and "helgolandicus" as species are too slight and inconstant to be relied upon.

In 1913 the numbers were lower, and the maximum was 4000 on July 28th.

In 1914 the maximum was 7320 on August 6th.

In 1915 again the numbers were low, the highest being 3232 on July 1st.

In 1916 a swarm appeared in the bay on July 11th, when over 12,000 were taken in a haul. A few days before a similar haul gave only 10 specimens, and a few days after 200. The average per haul at Port Erin over the ten years is only 266.

On the whole this record agrees well with that at Plymouth, which is "Common on and off from the end of April to the beginning of November, generally present in small numbers at other times" (Miss Lebour).

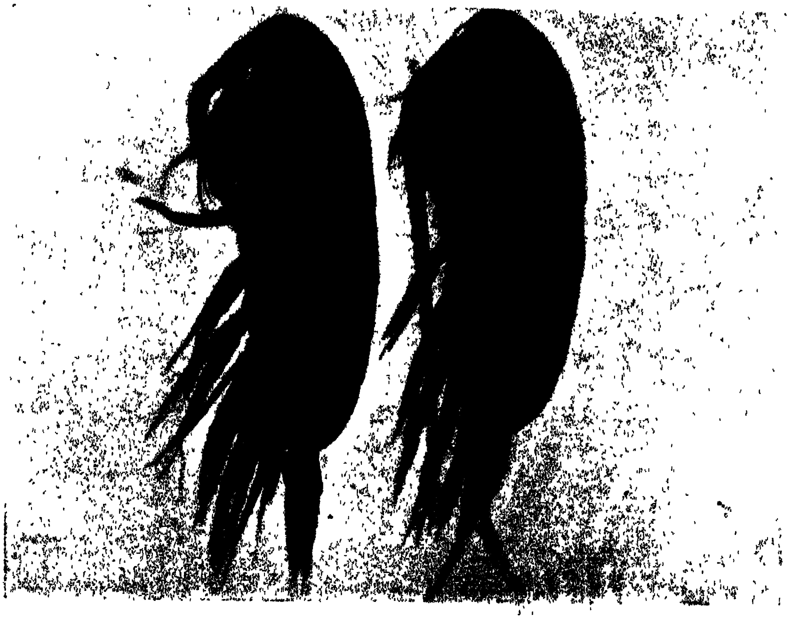

Fig. 13.—*Calanus finmarchicus*, from a photo-micrograph by A. Scott.

Calanus finmarchicus (fig. 13), as its specific name suggests, is a northern or Scandinavian form with a wide distribution through the colder waters of the North Atlantic. According to Ove Paulsen its home and centre of distribution lies to the south of Iceland.

In Loch Fyne on the west coast of Scotland, off Skate Island, *Calanus* appears to be present throughout the year in great quantities in deep water, at or near the bottom, along with *Euchæta norvegica* and *Nyctiphanes norvegica*. For example, in July 1907, off Skate Island in 104 fathoms, we caught 13,000 *Calanus* in one vertical haul, and on another occasion off East Loch Tarbert, in 76 fathoms, we got 10,000. We have also obtained from the yacht at various localities in the deep lochs on the west coast of Scotland large hauls of *Calanus* by means of vertical hauls when no specimens were obtained at the surface. In fact this Copepod seems to be permanently present in the deeper waters of these lochs.

In addition to these deep water specimens of *Calanus* we find on occasions, on the west coast of Scotland, large swarms on the surface, which may be the result of invasions from the ocean, and there is a considerable amount of evidence that such swarms are the cause of local mackerel fisheries.

Some years ago (1909) Dr. E. J. Allen and Mr. G. E. Bullen published * some interesting work, from the Plymouth Marine Laboratory, demonstrating the connection between mackerel and *Calanus* and sunshine in the English Channel; and Farran † states that in the spring fishery on the West of Ireland the food of the mackerel is mainly composed of *Calanus*. In the summer of 1913 we had an experience at Tobermory, in Mull, which I shall quote from two letters written from the yacht at the time, and published in 'Nature.'

"S.Y. 'Runa,' Tobermory, July 12th, 1913.

"On arriving in this bay last night we found that the local boats had been catching abundance of mackerel close to. We bought some for supper (good fish for a halfpenny each), and on dissection found that the stomachs of all of them were crammed full of fresh-looking *Calanus* (the individual Copepods being for the most part distinct and perfect), along with a few immature *Nyctiphanes* and larval Decapods. Professor Newstead and my daughter then noticed, while fishing over the side of the yacht, about 8 p.m., that the gulls in the bay were feeding in groups around patches of agitated water evidently caused by shoals of fish. On rowing out to these we saw distinctly the mackerel, large and small, darting about in great numbers in the clear water, and we also noticed every here and there on the smooth surface of the water—it was a beautifully calm evening—innumerable small whirls or circular marks which, looking closely, I found to be caused by large Copepoda close to the surface.

"About twenty years ago I sent a note to 'Nature,' from the yacht 'Argo,' in regard to large Copepoda (I think it was *Anomalocera* on that occasion, and the locality was further north, off Skye), splashing on the surface so as to give the appearance of fine rain; and this present occurrence at once reminded me of the former occasion, but here the Copepod was *Calanus finmarchicus* of large size and in extraordinary abundance. They could be clearly seen with the eye on leaning over the side of the boat, a small glass collecting jar dipped at random into the water brought out twenty to thirty specimens at each dip, and a coarse grit-gauze tow-net of about 30 cm. in diameter caught about 20 cubic centimetres of the Copepoda in five minutes.

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* Journ. Mar. Biol. Assoc. vol. viii. (1909) pp. 394-406.

† Conseil Internat. Bull. Trimestr. 1902-8, Planktonique, p. 89.

The mackerel were obviously darting about, occasionally leaping to the surface (which gave the gulls their opportunity) where the whirls, caused by the Copepoda, were thickest, and an examination of the stomach-contents of the fish on the yacht afterwards, showed us that the amount in one mackerel was about the same quantity as that caught by the tow-net in five minutes. Professor Newstead and I have made a count of 8 c.c. of the tow-net gathering, and estimate that it contains about 2400 specimens of *Calanus*. This would give about 6000 Copepods in the stomach of an average mackerel, or in a five-minutes' haul of the tow-net, on this occasion.

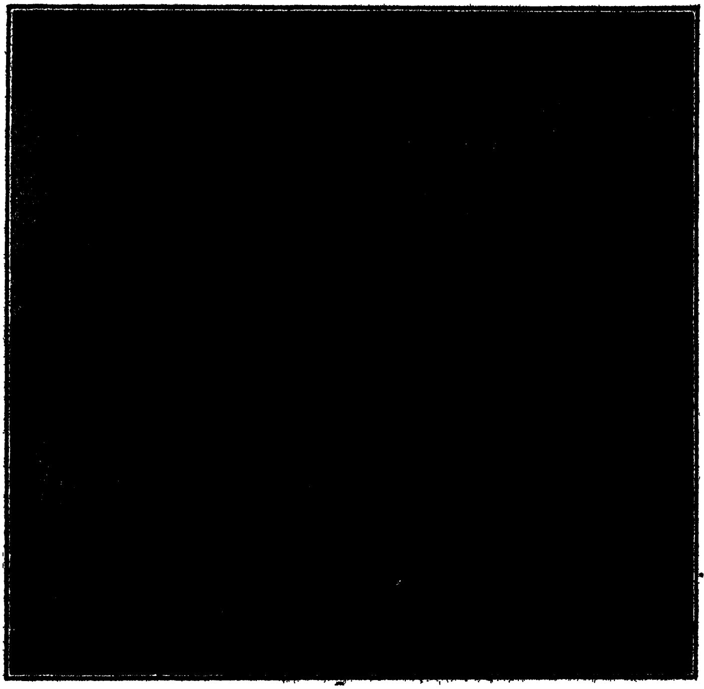

FIG. 14.—Photograph of exceptionally large hauls (about 1000 c.c. in a jar) of *Calanus* taken from the yacht 'Runa' in 1913 on the west coast of Scotland. The largest haul was estimated to contain at least half a million individuals.

"It may be added that these mackerel were evidently not being nourished in accordance with the views of Pütter, and were clearly able to fill their stomachs from the plankton around them." . . .

The following note, written some weeks later, records the conclusion of the matter, so far as that summer's observations went :—

"S.Y. 'Runa,' off Island of Eigg, August 12th, 1913.

"On getting back to Tobermory on Saturday, we found the plankton to be in marked contrast to its condition four weeks ago. The vast swarm of

Calanids has gone, and there are now no signs of mackerel feeding in the bay. In fact, the change has been noticeable for some days in the seas outside, and we have not been getting lately the large plankton catches that were usual in the latter half of July. On July 14th a haul of the large surface tow-net, in the open sea off Ardnamurchan, gave such a huge catch of *Calanus* (about 1000 c.c.) that we promptly took a second similar haul, and had it cooked as a sort of potted 'shrimp' confection for tea (sampled by ten persons, including the crew, who were much interested to try this new edible 'fish'); while on August 11th a haul of the same net, taken at the same spot, gave only a small catch of some 15 c.c., containing very few Calanids, along with the usual scanty summer zooplankton." . . . .

The importance of *Calanus* as a food for migratory pelagic fishes such as the mackerel cannot be doubted (see fig. 14).

PSEUDOCALANUS.

Pseudocalanus elongatus (Boeck) is widely distributed in the North Atlantic and is present in the Irish Sea throughout the year (fig. 15). It reaches its lowest level in January and February, and has its maximum in late summer and autumn (June to October in our records, generally September or October).

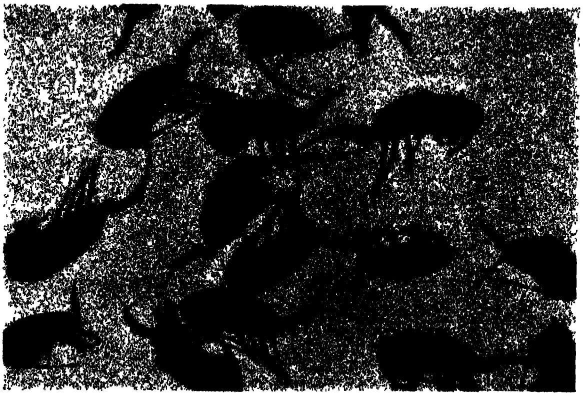

FIG. 15.—*Pseudocalanus elongatus*, from a photo-micrograph by A. Scott.

This Copepod comes next after *Oithona* as the second most abundant species in the Irish Sea, its average per haul over the ten years being 4583.

Some of the most important records are:—65,200 on May 20th, 1912; 91,960 on October 21st, 1912; 68,120 on June 24th, 1913; 60,600 on May 5th, 1916; 59,600 on September 25th, 1916; 58,200 on October 31st, 1912; 54,350 on July 31st, 1911; and many other records between 35,000 and 50,000 in these same months.

PARACALANUS.

Paracalanus parvus (Claus) is a southern form (fig. 16) which extends to the tropics and has a wide distribution. It is present in quantity only during autumn and winter in the Irish Sea, being practically absent between February and July, and having its maximum in September or October. The largest hauls are in autumn, for example, 59,460 on September 7th; 138,300 on September 10th; 53,500 on September 15th, all in 1914; 61,930 on August 24th, 1911; 49,800 on September 8th, 1910; 49,390 on September 7th, 1912; 44,060 on October 24th, 1912; while other large hauls in the same months range from 25,000 to 40,000.

FIG. 16.—*Paracalanus parvus*, from a photo-micrograph by A. Scott.

This is a species that has varied considerably in quantity from year to year, its average per haul ranging from 325 in 1907 to 5863 in 1914. In the present year, 1917, it was especially abundant at Port Erin in September, along with *Oithona*.

OITHONA.

Oithona helgolandica (= *O. similis*), Claus, is the most generally abundant Copepod throughout the year in the Irish Sea; but the months when it is taken in greatest numbers are June to November (inclusive) with the maximum generally in July. There may, however, be a second maximum later, in October or November.

The following may be quoted as exceptionally large hauls:—The highest, 225,450, is on July 18th, 1911, and the next highest, 199,300, is on November 9th, 1914; then we have 93,580 on July 28th, 1913, 87,530 on September 26th, 1912, and 83,350 on June 14th, 1910. We have twenty other records of over 44,000 each scattered over the months June to November. This is the Copepod which has the highest average number per haul over the ten years, viz., 8171 (see table, p. 190). Although this is a small species (fig. 17), still from its very great abundance it must be of considerable economic importance as a food-matter in the sea.

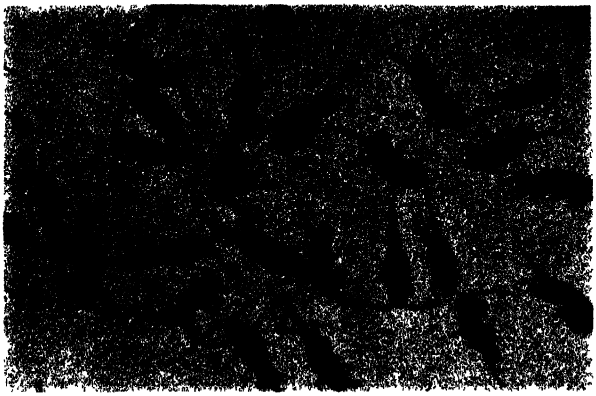

FIG. 17.—*Oithona helgolandica*, from a photo-micrograph by A. Scott.

ACARTIA.

Acartia clausi, Giesbr., is a summer species widely distributed over the North Atlantic, and present in greatest abundance in the Irish Sea from May to October (inclusive), and having a maximum generally in June, with another slighter rise in autumn, September or October.

FIG. 18.—*Acartia clausi*, from a photo-micrograph by A. Scott.

The following are some of our highest records:—59,490 on June 27th, 1912; 59,360 on August 24th, 1911; 52,200 on May 20th, 1912: 50,100 on June 2nd, 1913; 44,000 on September 29th, 1913; and 41,950 on June 17th, 1912. The average of this species per haul throughout the ten years is 2571. Swarms of this oceanic species (fig. 18) in summer may possibly be connected with an inflow of Atlantic water; but probably also large numbers appearing locally in enclosed areas may be the result of reproduction and development *in situ*.

In some cases *Acartia* has been found in unusual abundance quite close to the shore, and even in water of low salinity.

Towards the end of September, 1917, we emptied for cleaning purposes the large open-air fish-ponds at the Port Erin Biological Station, and when most of the water had been pumped out we noticed that what remained was swarming with small Copepoda. Every bucket and jarful that one removed for inspection was found to be densely crowded—as densely, in fact, as an average jar of plankton representing the contents of a standard haul. Some buckets of these Copepoda were used for feeding the lobster larvæ and some of the smaller fish and other animals in the Aquarium, and a small sample that was preserved was found to be a practically pure gathering of *Acartia clausi*. One specimen of *Centropages* was present in the tube amongst many thousands of *Acartia*, when Mr. Scott took the photo-micrograph shown in fig. 18.

TEMORA.

Temora longicornis (Müll.) is a very local species, which may be found on occasions swarming in great abundance in small areas of the sea, generally close to land. It is a summer species and its maximum is generally in June or July, but was in May in 1912, when the large hauls of 50,400 and 83,400 were taken on the 17th and 20th respectively. Other large hauls of this

FIG. 19.—*Temora longicornis* from the stomach of a Mackerel. From a photo-micrograph by A. Scott.

species in our records are :—45,530 on July 11th, 1916 ; 43,800 on June 11th, 1913 ; and 34,665 on July 26th, 1910. The average for this species per haul throughout the ten years is 1234.

Temora (fig. 19) is characteristic of coastal as opposed to Atlantic water, and is the only "neritic" form in our series. The other five are all usually classed as "oceanic," but as I have pointed out above most of them are really present throughout the year in the Irish Sea.

Temora longicornis is on occasions one of the most abundant of our Copepoda in the Irish Sea and must be of considerable importance as a food for fish and especially for the herring in summer. In the latter part of July and the first half of August, 1917, the shoals of herring to the west of the Isle of Man came unusually close to land and even penetrated into bays and creeks ; and during this time they were feeding mainly, if not wholly, on *Temora*. Late in July this Copepod was so abundant that its presence caused large patches of a red colour on the surface of the sea off Port Erin and around the Calf Island. These red patches were noticed by the fishermen, and were spoken of amongst them as being "fish-food" or "spawn." A large jarful from such a red patch, obtained by one of the fishermen, was brought to the laboratory and found to be swarming with small Copepoda, which on examination proved to be almost wholly *Temora longicornis* (fig. 20). About one-fourth part of the contents of the jar was preserved, and on being counted later on was found by Mr. Andrew Scott to amount to 50 c.c. of Copepoda, consisting of 33,340 *Temora* and 2 *Calanus*. Mr. Scott estimated the oil present in 9 c.c. of the dried *Temora* at 2·47 per cent. of the weight, which was 0·925 gramme.

FIG. 20.—*Temora longicornis* from the "red patches." From a photo-micrograph by A. Scott.

During this same time the men were catching herring in quantity unusually close inshore in the neighbourhood of the red patches, and on examining, in the laboratory at the Biological Station, the stomach-contents of a number of these herrings, I found in every case that the stomach contained a mass of red material which was obviously, under the microscope, the broken-down remains of Copepoda. A few Crab zoea were recognisable, but the bulk of the material consisted undoubtedly of the Copepoda. Mr. Scott examined 5 c.c. of the stomach-contents for me, and found that it contained 975 easily recognisable specimens of *Temora*. A photograph (fig. 21), which Mr. Scott

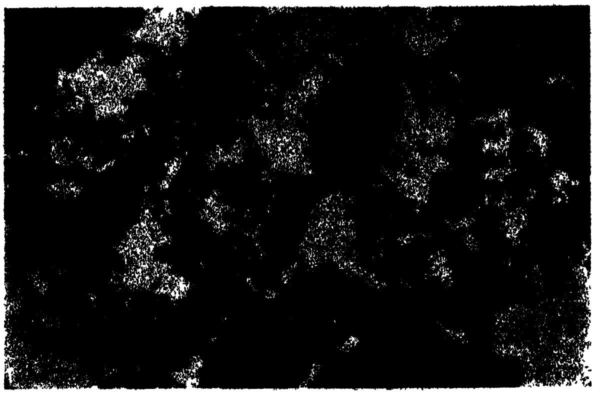

FIG. 21.—*Temora* remains from the stomachs of the Herring. From a photo-micrograph by A. Scott.

has made from one of the microscopic preparations, shows appendages that undoubtedly belong to this Copepod, while here and there in the stomachs complete specimens of *Temora* are to be seen. It is not possible to doubt that during these weeks, at the height of the summer herring fishery in the Irish Sea, the fish were feeding mainly upon this species of Copepod.

We recorded a similar occurrence off the Lancashire coast a few years ago, when in July 1913, at the time of an abundant mackerel fishery off Walney Island, the stomachs of some of the fish were found to be full either of *Temora* alone or of *Temora* mixed with *Isias* and a few other Copepoda (see fig. 19, p. 198). A few herrings from the Port Erin fishery of July 1916 were found by Mr. Scott to be feeding mainly on *Calanus*.

CONCLUDING REMARKS.

Many food-fishes are known to feed upon Copepod plankton during at least some portion of their life. The Loch Fyne herrings are frequently at the time of a fishery found to have their stomachs filled with *Euchæta* or *Calanus*. Mackerel, in the English Channel and to the S.W. of Ireland and elsewhere, have been recorded as feeding on *Calanus*. It has been shown in this paper that in Hebridean Seas the mackerel and in the Irish Sea herrings, at a time when they are present in great abundance, are feeding on some prevalent form of Copepod, such as *Calanus* or *Temora.* Other similar cases could no doubt be quoted and are known to marine biologists.

Then, as to demersal fish—young plaice, after their metamorphosis, feed chiefly on the smaller Copepoda, while in younger stages the post-larval plaice feeds upon Diatoms. We have noticed at the Port Erin Biological Station the post-larval plaice with its stomach showing of a golden brown colour from the Diatoms with which it was filled, and we have watched in a shallow pond the metamorphosed young plaice darting backwards and forwards pursuing, catching, and devouring the individual Copepoda. It is known that these Copepoda in their turn feed in part at any rate on Diatoms, so our two main constituents of the plankton are undoubtedly concerned in the nourishment of either young or adult fishes useful to man.

The association of shoals of fish with abundance of plankton is the result of the fact that, in order to get an adequate quantity of planktonic food, the fish must seek out and capture the Copepoda. In other words, the fish must go where the plankton is abundant and must in its movements follow the movements of the shoals of Copepoda. It is the very poverty of the plankton in some sea-areas, insisted on by Pütter, Lohmann and others, which makes it necessary for plankton-eating fish to move about in search of more abundant supplies.

Consequently it is of importance to show, as we now can, that in our coastal seas at least, where the fisheries we are interested in take place, the plankton is not uniformly distributed. Many of the Copepoda occur very definitely in local swarms, and various localities and depths are characterised at the different seasons by particular assemblages of plankton. It is therefore reasonable to believe, in view of the facts given above as to the association of fish and plankton, that these variations in the distribution must have a marked effect upon the presence and abundance of at least such migratory fish as herring and mackerel, and also of the shoals of post-larval young of many of our other food-fishes.

No less than three masses of sea-water of different origin and character may enter or affect the British seas in varying quantity, viz.:—(1) Arctic water such as normally surrounds Iceland and the east of Greenland, and may extend further southwards and eastwards towards Norway, the Faroes, and Shetlands; (2) Atlantic ("Gulf-stream Drift") water which impinges on the western shores of Ireland, and may flood the English Channel and extend round the Shetlands or down into the North Sea; and (3) "Coastal" water such as flows out from the Baltic and, mixed with the other waters, bathes the coasts of N.W. Europe generally, and to a large extent surrounds the British Islands.

The Irish Sea may be regarded as primarily an area of coastal water, which is, however, liable to be periodically invaded to a greater or less extent by bodies of warmer and salter Atlantic water (re-inforced possibly by portions of a deeper outflowing Mediterranean current) carrying in oceanic plankton, and more rarely perhaps by Norwegian or Arctic water causing an invasion of northern organisms. The variations which we find in different years in the nature and amount of the plankton at the same localities no doubt depend to some extent upon the volume and period of such southern or northern invasions; but they may depend also upon other factors, such as the weather (temperature, sunshine, rainfall, wind, etc.) at the time, and previously.

Of the six Copepoda discussed above only one—*Temora*—is a neritic form; the others are all usually regarded as oceanic, that is as having their true home and centre of distribution somewhere to the north, west, or south in the open Atlantic.

The following list gives an approximate indication of what is supposed to be the source of these five oceanic Copepoda:—

Calanus.—N. Atlantic, about Iceland ("Boreal oceanic").
Paracalanus.—Southern, temperate and tropical Atlantic.
Pseudocalanus.—N. Atlantic ("Boreal oceanic").
Oithona.—N. Atlantic ("Boreal oceanic").
Acartia.—N. Atlantic ("Northern styli-plankton").

Some no doubt live on during the year in the Irish Sea, but these indigenous populations are probably reinforced by waves of immigration from outside.

In the case of our Diatoms some of the species of a genus may be neritic and others oceanic, as is shown in the following list, where (N.) stands for neritic and (O.) for oceanic, and a (?) indicates that the evidence seems to me conflicting or inconclusive [*]:—

Biddulphia mobiliensis (N.), *B. sinensis* (O.).
Coscinodiscus radiatus (O. ?), *C. concinnus* (N.), *C. Grani* (N.).
Lauderia borealis (N.).
Chætoceras boreale (O.), *C. criophilum* (O.), *C. decipiens* (O ?), *C. densum* (O.), *C. contortum* (N.), *C. debile* (N.), *C. diadema* (N.), *C. sociale* (N.), *C. subtile* (N.), *C. teres* (N.).
Thalassiosira gravida (N.), *T. Nordenskioldi* (N.).
Rhizosolenia alata (O.), *R. semispina* (O.), *R. setigera* (N.), *R. Shrubsolei* (N. ?), *R. Stolterfothi* (N. ?).
Guinardia flaccida (N. ?).

It is remarkable how small a number of forms make up the bulk of the macro-plankton throughout the year. These half-dozen kinds of Diatoms and half-dozen Copepoda are the all-important organisms upon which our fate depends so far as concerns food from the sea. That shoals of migratory fish such as herrings and mackerel are attracted in summer and autumn by dense swarms of certain Copepoda such as *Calanus* and *Temora* can no longer be doubted; and there is abundance of evidence that earlier in the year the young stages of other food-fishes, such as plaice, are nourished first by Diatoms and when larger by the smaller Copepoda. These conclusions, however, do not finish the matter. There remains in the sea the much more minute Protozoa and Protophyta of the Nannoplankton, which to a large extent escape through the meshes of our plankton nets and which are doubtless of great importance as the food of Copepoda and other large organisms which in their turn nourish fish.

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[*] The matter was discussed more fully some years ago in a paper by Herdman and Riddell in Trans. Biol. Soc. Liverpool, xxv. (1911) p. 178.

There are several other interesting lines of further investigation which open up as collaterals from plankton investigation. One of these is the origin of the great vernal phytoplankton maximum. In the spring there is an awakening of the plant-life of the sea comparable to the growing of the grass and the budding of the trees on land. This cannot be due to any rise in temperature, as the sea at the time that the Diatoms start their active growth and reproduction is at its coldest. We have series of observations extending over more than ten years showing that the water of Port Erin bay is generally of lower temperature in March than in December or January. Of the various causes for the rise in the Diatom curve in these cold waters of early spring I have for some years * regarded with greatest favour the view suggested first by Sir John Murray, viz., the increase in sunlight at that time of year. In that case it would be a photosynthetic phenomenon—the increased solar light energy enabling the Diatoms to obtain from their environment by photosynthesis the materials required for their growth and reproduction. The view that the spring increase in plankton is due to changes in the alkalinity of the water does not in my opinion conflict with the photosynthesis theory but is supplementary to it. The position in regard to the relation between variations in alkalinity and in the plankton, in our district, is as follows:—

The sea around the Isle of Man is a good deal more alkaline in spring (say April) than it is in summer (say July); and during the years 1912–14 Professor Benjamin Moore, by examining samples of sea-water periodically at the Port Erin Biological Station, was able to show † that the alkalinity, which gets low in summer, increases somewhat in autumn, and then decreases rapidly, to disappear during the winter; and then once more, after several months of a minimum, begins to come into evidence again in March and rapidly rises to its maximum in April or May. This periodic change in alkalinity will be seen to correspond roughly with the changes in the living microscopic contents of the sea represented by the phytoplankton annual curve, and the connection between the two will be seen when we realise that the alkalinity of the sea is due to the relative absence of carbon dioxide. In early spring, then, the developing myriads of Diatoms in their metabolic processes gradually use up the store of CO_2 accumulated during the winter and so increase the alkalinity of the water, till the maximum of alkalinity, due to the reduction in amount of carbon dioxide, corresponds with the crest of the phytoplankton curve in, say, April. Prof. Moore has calculated that the annual turn-over in the form of carbon which is used up or converted from the inorganic into an organic form probably amounts to something of the order of 20,000 or 30,000 tons of carbon per cubic mile of sea-water in the Irish Sea; and this probably means a production each season of about two tons of dry organic matter, corresponding to at least ten tons of moist vegetation, per acre—which shows that we are still very far from getting from our seas anything like the amount of possible food-matters that are produced annually.

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* See "Intensive Study, &c." Part III, p. 260, 1910, Trans. Biol. Soc. Liverpool, xxiv.

† Trans. Biol. Soc. Liverpool, xxix. (1915) p. 233.

Testing the alkalinity of the sea-water may therefore be said to be merely ascertaining and measuring the results of the photosynthetic activity of the great phytoplankton rise in spring due to the daily increase of sunlight.

Other possible causes, more or less related to the above, have been suggested —such as Brandt's hypothesis that the fluctuations in the phytoplankton depend upon the accumulation, and then the exhaustion, of necessary inorganic food-matters in the water, such as nitrogen or phosphorus compounds or silica ; and the view of Nathansohn, Gran and others that vertical currents, carrying up food-matters from the deeper water, have a powerful effect upon the seasonal development of surface plankton. These may be contributory causes or may be effective locally, or on occasions ; but it seems probable that a widespread phenomenon of enormous amount such as the vernal increase of phytoplankton must depend upon an equally widespread and powerfully-acting cause such as the rapid increase in the amount of solar light energy which marks the lengthening days of the year in early spring.

THE PERCY SLADEN TRUST EXPEDITIONS TO THE ABROLHOS ISLANDS (INDIAN OCEAN).

Under the Leadership of Prof. W. J. DAKIN, F.L.S., F.Z.S.

REPORT I.—Introduction, General description of the Coral Islands forming the Houtman Abrolhos Group, the Formation of the Islands. By W. J. DAKIN, D.Sc., F.L.S., Professor of Biology, University of West Australia.

(PLATES 10–14, and 12 Text-figures.)

[Read 1st February, 1917.]

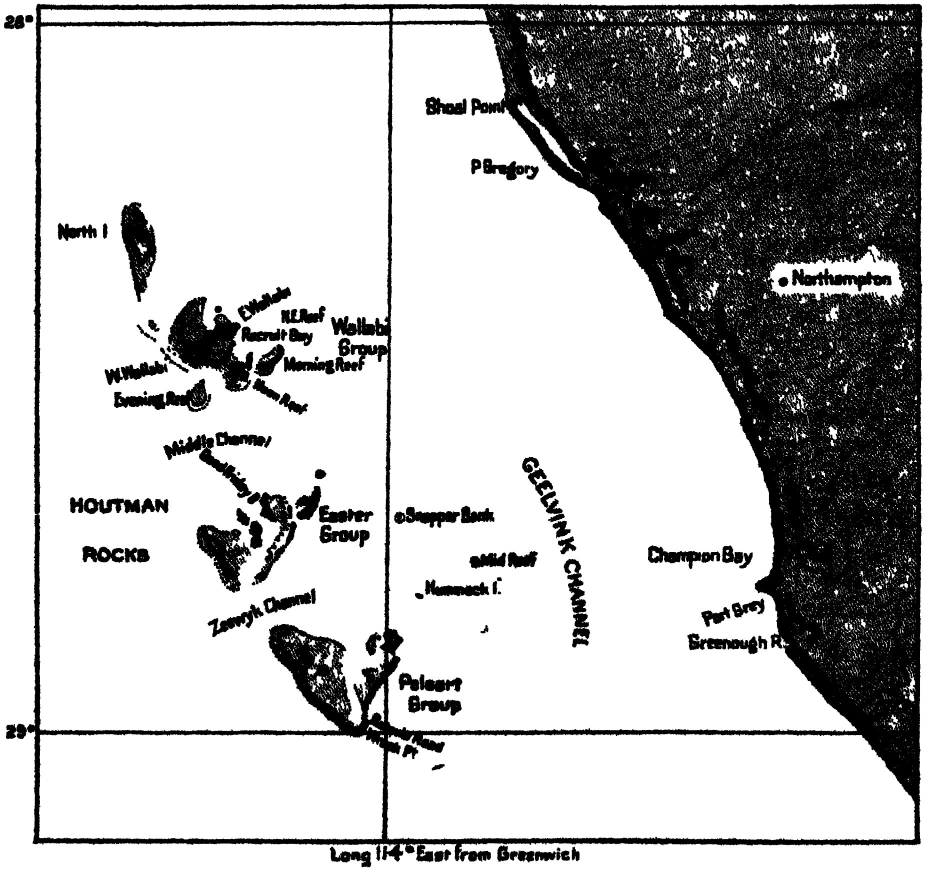
INTRODUCTION.

SHORTLY after my arrival in Western Australia in 1913 my attention was drawn to the interesting position of certain coral islands known as the Houtman's Abrolhos Islands. I determined to visit the group at the earliest possible date, and to this end applied to the Trustees of the Percy Sladen Trust for a grant in aid. An expedition was planned and left the Australian Coast in November 1913 for the islands. On this occasion I was fortunate in having a very able colleague in Mr. W. B. Alexander, M.A., of the West Australian Museum, and the grant of the Percy Sladen Trustees was supplemented by aid from the University of West Australia and the West Australian Museum. Part of our equipment was conveyed direct to the islands from Fremantle, but the personnel with the rest of our apparatus and stores, etc., travelled by train to the port of Geraldton, where the fishing lugger 'Queen,' a boat of 22 tons, awaited us. The 'Queen' is one of a fleet of fishing-boats which makes Geraldton its headquarters, and fishes the waters round the Abrolhos Islands, and as far north as Shark's Bay.

Geraldton is a port of about 3500 inhabitants, situated on the coast of Western Australia in latitude 28° 46′ S. Although only a small town it ranks as the second or third port in Western Australia, and is the centre for a large agricultural and pastoral area, as well as the Murchison goldfield. It marks the most northerly point on the coast which can be reached by train from Perth, and it will be seen on reference to a map that a great length of the coastline of Western Australia remains to the North and can only be visited with difficulty. There are a few ports which are reached by regular steamers from Perth, but between these places the coast might almost still be termed unexplored; this certainly holds good, from the biological point of view, for the entire coast north of Geraldton with the exception of Shark's Bay.

The Abrolhos Expedition of 1913 extended over a period of three weeks, during which time we worked the 'Queen' from islet to islet, and combined shore collecting with biological and geological observations on the islands, and some dredging in the lagoons and between the island groups. Extensive collections resulted and many observations of interest and importance were made. As a result it was felt highly desirous that a supplementary expedition should be arranged as part of a scheme embodying the investigation of the North-Western Coast. Fortunately the authorities at home came once more to the rescue, and with the aid of a further grant from the Percy Sladen Trustees, together with help from the Royal Society Grant Committee and the British Association, a second expedition was made possible. On this occasion I was assisted by my colleague, Mr. A. Cayzer, B.Sc., Assistant Lecturer in Biology, University of West Australia. The fishing lugger 'Ada' was chartered and we left Geraldton for the Abrolhos in October 1915, four weeks being spent amongst the islands. I was fortunate in having more hydrographic equipment at my disposal on the second expedition, and a rowboat fitted with a motor was of invaluable service in connection with work in the lagoons. I can heartily recommend

Text-figure 1.



General Map of the Houtman Abrolhos Islands.

this very cheap type of motor craft for use in sheltered waters such as those of the lagoons. It was even possible to dredge with a small instrument 2 feet long and weighing, without sinkers, 12 lbs., in a most satisfactory manner. Much more time was spent in dredging on the second expedition, the small dredge being worked from the rowboat in the lagoons, whilst an Agassiz trawl was used from the lugger in the more open waters. On both expeditions the skippers and crew were Scandinavians and they helped enthusiastically in the work.

On both occasions we took with us camp equipment. The working plan was as follows. The lugger was sailed to a convenient and sheltered anchorage where we intended to work, and usually quite close to an islet (large or very small as the case might be). A camp was then set up on shore, where my colleagues and myself slept, whilst the crew remained on board. Two or three days might be put in at one anchorage in this way, or we might shift lugger and camp every day according to the work carried out. On some occasions the shore collecting, surveying, and work in the lagoons with the dinghy, occupied all our efforts, so that the lugger was left undisturbed for several days. On other occasions when the weather was suitable for dredging in the open sea, we would start early in the morning and leave our camp on shore, to return in the afternoon with the spoil, which needed sorting, labelling, and preserving.

One of the great difficulties in connection with work at the Abrolhos Islands is to find the right kind of weather. For the greater part of the year the winds and sea are too unruly for continued work in these waters, except from a large vessel, and a large vessel could not be used amidst the coral islets. It appears that the best times are *between* the two well-marked seasons, Summer and Winter (dry and wet seasons), *i.e.* the months of October and November on the one hand and April and May on the other. Both of our expeditions were carried out between winter and summer, but we were not nearly so fortunate on the second occasion, although longer at the islands. On one occasion we hung with two anchors out whilst a gale blew for twenty-four hours ; a nasty coral-reef, just submerged, was situated only about twenty feet behind our stern. No accidents happened, but our work was delayed for several days owing to the bad weather. On another occasion, however, the ocean swell was so reduced to leeward of one of the islands that we were able to follow the outer reef and examine it from the motor dinghy.

Reversing thermometers were used on the second expedition in conjunction with the Ekmann water-bottle, but we were too short of workers to initiate a scheme for the complete oceanographical investigation of this region and were forced to be as economical as possible. Our plankton hauls were made chiefly with the object of comparing the plankton of the lagoons with that of the ocean outside, and for this purpose we usually aimed at taking hauls in both places on the same day, and about the same time. The catches have not yet been examined in detail, but it was fairly obvious, each time, that the plankton of the lagoons contained large quantities of dead organisms and much debris. On the second expedition blasting gelignite was tried as an experiment for the capture of fish. A detonator was pushed into a stick of gelignite, and, after lighting the fuse, the whole thing was thrown overboard. It only worked satisfactorily over the reefs in moderately shallow water, but we could often throw it amidst shoals of coral-haunting fish in these regions. The burning fuse appeared to attract the fish nearer to the explosive rather than frighten them away. After the explosion, numerous fish would appear on the surface. They were not usually dead, but swimming just as if the gas-bladder were distended. Some species did not rise at all, and it would appear that the ascent of the fish immediately after the explosion is not due to death, but to physiological conditions following the shock.

Another experiment was the use of chloride of lime as a poison in rock-pools. This was suggested to me by Professor Starr Jordan and worked very well, but owing to the tides being rather poor and the wind high on many days when we could have utilized this, it was only tested on a few occasions.

The Houtman's Abrolhos lie about 40 miles away from the coast of Western Australia, on the very edge of the continental shelf in latitude 28° 40′ S. (see map, text-fig. 1). The depth of water over the shelf between the Abrolhos and the mainland is very uniform and averages about 25 fathoms, whilst the same depth occurs between the different groups of islets. A few miles west of them the sounding-line gives depths of hundreds of fathoms.

Unfortunately, the Abrolhos Islands are poorly charted and small maps on a reasonable scale deal only with two of them, together with a small area of lagoon in each case which was probably considered to be well sheltered and providing good anchorage. There are no lights of any kind on the islets, and in consequence the fishermen, who have spent years about this area, will not approach close when the sun has set. As a matter of fact, navigation in the lagoons and about the small islets is only safe when the sun is high, and a hand stationed in the rigging can spot the submerged coral-reefs which occur here and there. Coastal steamers give the Abrolhos a wide berth, but more than one ship has finished her life on these barren reefs. In fact, the history of the islands almost commences with a wreck (1629) and the coral reef of the Pelsart Island is to-day dotted with the scattered remains of a steamer, the 'Windsor,' which became a total wreck a few years ago.

Islands in such a position as the Abrolhos—in close proximity to a continent—are full of interest to the biologist, and this is especially the case when they are coral islands. It is not surprising then to find that they have already been visited by one or two collectors. They were discovered by the Dutch navigator Houtman in the year 1619, but the name Abrolhos is a contraction of a Portuguese phrase meaning "keep your eyes open." They are now more frequently called the Abrolhos Islands. The West coast of Australia was known before this date, and Saville Kent is quite incorrect in stating that it was Pelsart's discovery of the Abrolhos (1629) that led to the "earliest recorded discovery of the great island-continent of Australia."

The wreck of Pelsart's ship (one of the Dutch East Indian Co.'s vessels) in 1629, led to one of the most romantic episodes in the early history of West Australian exploration.

Pelsart in command of the 'Batavia' left Texel on October 28th, 1628, for the East Indies in company with several other ships, all of which were equipped and commissioned by the Directors of the Dutch East India Company. The ships became separated and the 'Batavia,' continuing her course alone, got among the coral reefs of the Abrolhos Islands and struck before sunrise on June 4th, 1629. Trouble followed thick and fast, and the tribulation of the passengers was accentuated by the drunkenness and disorderly conduct of the soldiers and sailors. The ship's company were, however, eventually landed on two of the small islands of the lagoon in the Pelsart Atoll, and much of the provisions and treasure was also salved. Unfortunately, there was a great lack of water, and as we have already seen, little or none is to be obtained on these islands. This trouble accentuated the spirit of unrest which had broken out, and Pelsart finally decided to set out and seek for water. A section of his crew appeared to be very ripe for mutiny.

For a few days the islands were investigated for water with little success, and then Pelsart set off to the mainland. The mainland, however, seemed to offer no better prospects, and for some time the men were unable to land owing to the surf. Drifting northwards some of the crew eventually made a landing by swimming ashore, but an inhospitable country dispelled all hopes, and ultimately Pelsart decided to make for Batavia in order to seek assistance and report to the Governor the misfortunes which had befallen them. He reached that place safely on July 5th, after a journey of upwards of 1700 miles in an open boat.

Tragic events had in the meantime taken place at the Abrolhos Islands. The Supercargo of Pelsart's ship, a thorough villain, named Cornelis, resolved to take up the life of a pirate on the high seas. To this end, he and his accomplices determined to murder in cold blood all the ship's company (220 souls) with the exception of about 38, and then capture the rescue vessel which Pelsart was expected to bring back with him. By this time the passengers, soldiers, and crew were occupying three of the lagoon islands, some of them having moved to the third in search of water. Cornelis and his company were on the largest island. The murders were carried out on two of the islands, only a few boys and some women being spared. A few men escaped, however, from this hell and reached the third island with the news, whereupon the party (now forty-five in all) led by a man named Weybehays resolved to defend themselves. Cornelis, who had assumed the title of Captain-General, sent two expeditions against them, but these being defeated he determined to gain his ends by more subtle means. Unfortunately for himself, he was hoist with his own petard, taken prisoner, and some of his men were killed. The rest of the mutineers remained on their islands awaiting the arrival of Pelsart, who had been given assistance and a ship at Batavia. He reached the Abrolhos on September 13, eagerly awaited by the two opposing parties, but four of the third island defenders managed to reach him first and acquainted him with the sad state of affairs. When the mutineers arrived to capture the ship, Pelsart and his men were ready for them. The boarding party was captured, and the rest of the ruffians on their island experienced a like fate. After an investigation of the tragedy, Cornelis and his associates were tortured and put to death—they had murdered over 120 innocent souls,—two other prisoners were marooned on the coast, the survivors of the wreck and mutiny eventually reaching Batavia in safety.

The disaster to Pelsart's ship was not the only one experienced by the Dutch at the Abrolhos—for which reefs their ships seemed to have an unfortunate liking. The 'Luytddorf' is supposed to have been lost here in 1711, whilst in 1727 the 'Zeewyk' was wrecked on the western reef of the Pelsart Atoll.

Pelsart described some of the forms of life met with on the islands and in so doing gave a most interesting account of the wallaby (*Macropus eugenii*, Desm.) which still abounds on two of the islands. This was one of the first written descriptions of a member of the kangaroo family to be given to the world. The diagnosis runs as follows:—"Besides we found in these islands large numbers of a species of cats which are very strange creatures. They are about the size of a hare, the head resembling the head of a civet cat, the fore paws are very short, about the length of a finger, on which the animal has five small nails or fingers resembling those of a monkey's fore paw. The two hind legs on the contrary are upwards of half an ell in length, and it walks on these only on the flat of the heavy part of the leg so that it does not run very fast. Its tail is very long like that of a long-tailed monkey. If it eat it sits on its hind legs and touches its food with its fore paws just like a squirrel or monkey.

"Their manner of generation or procreation is exceedingly strange and highly worth observing. Below the belly the female carries a pouch into which you may put your hand. Inside this pouch are her nipples; we have found that the young ones grow up in this pouch with the nipples in their mouths. We have seen some young ones lying there which were only the size of a bean, though at the same time perfectly proportioned, so that it seems certain that they grow there out of the nipples of the mammæ from which they draw their food until they are grown up and ready to walk. Still, they keep creeping into the pouch even when they have become very large and the dam runs off with them when they are hunted."

It is worthy of note that the Abrolhos Islands were charted by H.M.S. 'Beagle' under Wickham and Stokes a few years after Darwin's famous voyage in that ship. The vessel was some time at the islands and observations were made on the tides and specimens of the fauna were collected. Most of the names of the islets and passages were given at this time.

Darwin himself refers to the Abrolhos Islands in his famous work on Coral Reefs. He had, however, very little information concerning them, beyond that reported by the surveying ships.

The only serious biological investigations of the Abrolhos prior to our visits were made by naturalists who were attracted by the bird-life. One marine biologist, however, had visited the islands, namely Saville Kent. Whilst making a survey for the Government of Western Australia in 1894, this keen naturalist paid a flying visit to the Abrolhos. He was evidently impressed by them, for in the preface to his work 'The Naturalist in Australia,' he writes (referring to the development of the scientific potentialities of the country) :—"As an indication of the leading position Western Australia is eligible to occupy with relation to one important biological subject, reference may be made to that chapter which deals with the Houtman's Abrolhos. As there demonstrated, very exceptional facilities prevail at that place for the conduct of reef-boring operations and for the prosecution of all methods of investigation relating to coral and coral-life."

A considerable number of terrestrial vertebrates, particularly lizards, were obtained by Gilbert, who visited the islands on behalf of Gould the ornithologist. These specimens have been described in the British Museum Catalogues on the Lizards, Snakes, and Batrachia respectively. After Gilbert's collecting excursion, the next naturalist to visit the Abrolhos was A. J. Campbell, F.L.S. A paper on the zoology of these islands by this worker appeared in the Reports of the Australian Association for the Advancement of Science, Melbourne, 1890. Campbell visited this group in December, 1889. Beyond a few remarks about the Mammals and Reptiles he deals only with the bird-life. Campbell states that the Abrolhos form the greatest "rookery for sea-birds in Australia, and by reason of their geographical position in the sub-tropics, perhaps afford suitable breeding grounds for a greater number of species than any other distinct or limited spot in the world."

The next paper to appear dealing with the Abrolhos was a short article by Helms, who visited the islands in 1898. This author names several plants, speaks in a general way of the corals and fishes, and devotes most attention again to the birds. Another paper on the bird-life was written by Chas. G. Gibson and published in the 'Emu,' 1908–1909.

It will be seen that whilst the mammals, birds, reptiles, and amphibia have been referred to by three or four visitors to the Abrolhos, nothing in any detail has been published on the marine fauna beyond the work of Saville Kent.

Kent considered that the marine fauna of the Abrolhos was essentially a blend of tropical and temperate species. The tropical species were *not* to be found on the adjacent coast. Rich coral growths were to be seen everywhere (the islands were stated to be almost entirely composed of coral), but the living species were *not* the extra-tropical forms to be seen on the coast in this latitude, but were tropical types.

The Percy Sladen Trust Expeditions to the Abrolhos Islands in the years 1913 and 1915 have been conducted, in the first place, for an investigation into the structure and formation of these coral islets, and in the second place for the purpose of collecting information regarding the fauna and marine flora of this region of the Indian Ocean and West Australian coast. In connection with the latter aim we were particularly interested in the statements made by certain authors (Saville Kent, and Michaelsen of the German Expedition to South-West Australia) that the marine fauna of the Abrolhos was entirely different from that of the coast in the same latitude and only 40 to 50 miles away. We have collected some data with regard to the Hydrography of these regions, but it is extraordinary how little is known even of sea temperatures on the Australian coast, while numerous problems await investigation in connection with the tidal phenomena. It is a pity that the means of communication along the West Australian coast should be difficult and costly, but probably in the future, when this large State has its present vast spaces occupied by energetic emigrants, these difficulties will disappear. The time may even come when the scientific investigation of these coastal waters, with their valuable products of pearl-shell and fish, will be recognised as of just a little importance.

The present paper is concerned with a general description of the Abrolhos Islands and includes an account of their structure and formation. Other papers will follow dealing with the collections obtained on the two expeditions. One paper on a new species of Enteropneusta has already been completed. A short account of the Vertebrates, by Mr. W. B. Alexander, M.A., is also ready. The Sponges are now in the hands of Professor Dendy, and Professor W. A. Herdman has the Ascidians. The Holothurians are being worked up by Dr. J. Pearson of the Colombo Museum, the other Echinoderms by H. L. Clarke. The remaining groups have not yet been distributed owing to the dislocation of work consequent on the war.

The study of the marine fauna of the Abrolhos Region and the North-west coast of Australia forms an interesting sequence to biological work at Ceylon, and in particular to that of Stanley Gardiner at the Laccadive and Maldive Islands. We have found the reports of Stanley Gardiner's expedition, both on the fauna and the formation of the islands, of very great service.

GENERAL DESCRIPTION OF THE ISLANDS.

The islet group of the Abrolhos extends between 28° 15′ and 29° S. lat. and consists of a large number of islands, the smallest of which are only a few square yards in area and generally uncharted. There is urgent need of a survey, for the maps of the islands leave much to be desired and we often had evidence of the inefficiency of the charts.

The archipelago (for such it might be termed) is about 50 miles in length, and the islands occur in four groups. The most northerly group consists, however, of a single island, North Island, whilst the others (the Wallaby, Easter, and Pelsart Groups) comprise a number of islets which according to our views are closely related to one another. These four collections of islands are separated by channels whose depths are approximately the same as those between the entire Abrolhos Group and the mainland.

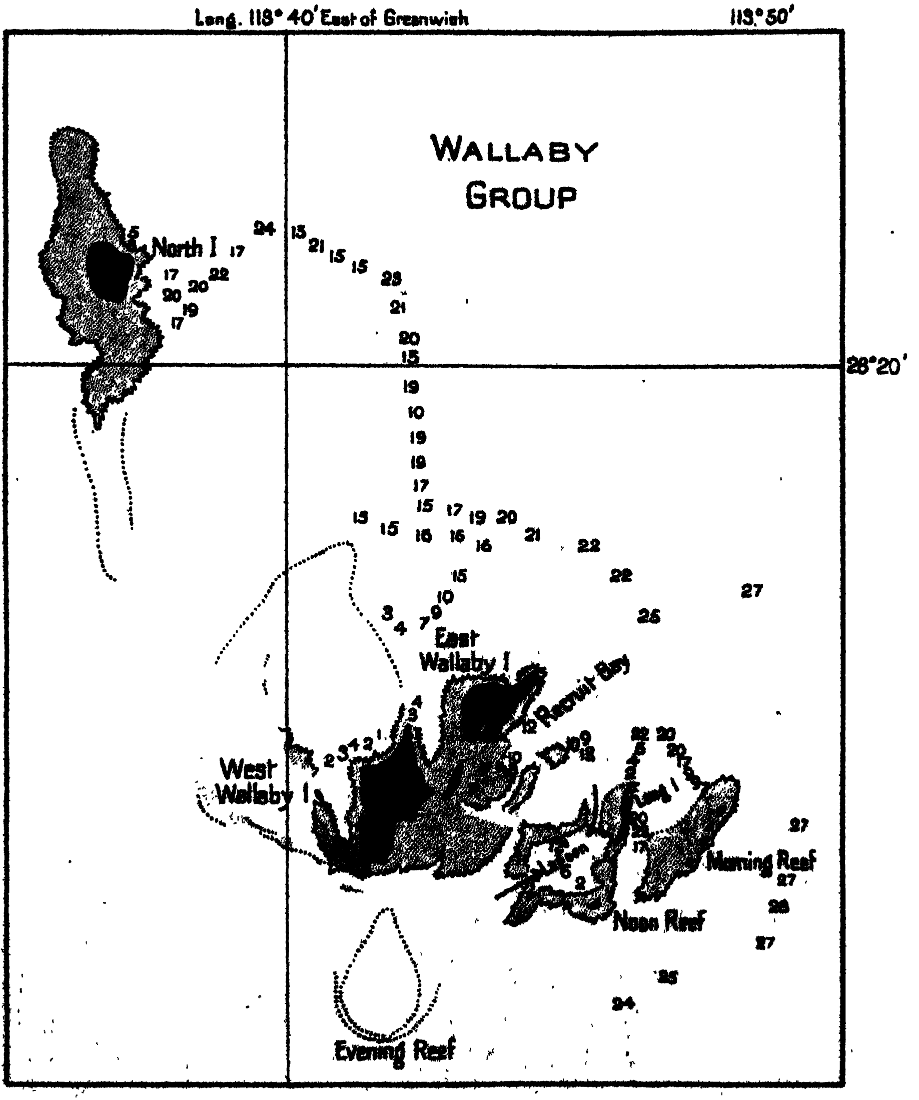
It may be noted as a characteristic feature, that all the islets occur on a line running roughly N.N.W.–S.S.E. Furthermore, if an island is much longer than it is broad (and this is frequently the case), the long axis usually runs almost north and south. The submerged reefs are often found to be running in the same direction.

It is usual to leave Geraldton about midnight or early in the morning, so that the islands will not be reached before the sun is well up. It is difficult to observe submerged reefs if the sun's rays are striking the water very obliquely. As a matter of fact, on each occasion that I have visited the islands the night start was quite unnecessary, for unfavourable winds and rough sea prevented us sighting the islands until late in the following afternoon.

Owing to the low elevation of the islands (usually about 8 feet above sea-level), with the exception of some to be mentioned presently, they are not seen until one is quite close. The picture presented is somewhat uninteresting, for the vegetation covering them is very scanty and consists of low bushes. No palm trees occur whatever, the largest plants being mangroves, but these are by no means common and occur on the lagoon flats, so that they are rarely visible from the sea. The gorgeous pictures made by the living coral below the glass-like surface of the water of the lagoons more than makes up for the uninteresting appearance of the surface of the islands. Coral is everywhere in evidence and appears to be growing luxuriously, although the Abrolhos are situated on the extreme southern limit of coral-reef formation.

The islands would be quite uninhabited were it not for a few guano workers who come over for the summer months only, and frequent some small island or part of a larger one. The fishing luggers are, however, very frequent visitors. These boats are chiefly manned by Italians or Scandinavians and sail from Fremantle or Geraldton. They may fish in the deeper waters round the islands, or send one or two small boats amongst the reefs, whilst keeping the lugger off during the day. At night, the numerous sheltered regions between the islets are available, and in case of storms a ready harbour is at hand, although, as previously pointed out, it is useless trying to enter the lagoons after sunset.

Text-figure 2.



North Island (see map, text-fig. 2) is the most northerly of the Abrolhos Group. It is situated about nine miles north of the Wallaby (or Wallabi) Isles, and is about one square mile in area. The Wallaby Group proper (see map, text-fig. 2) consists of two large islands, the East and West Wallaby Islands, and a number of small ones which are either unnamed or bear local names given by the fishermen. The West Wallaby Isle is the largest of the Abrolhos Group.

About 14 miles south of the Wallaby Group is situated the Easter Group (see map, text-fig. 1, p. 128). The largest of this collection of islands is Rat Island, which, however, is much smaller than either the East or the West Wallaby Islands.

The Zeewyk Channel (about seven miles across) separates the most southerly islands of the Easter Group and the northern reefs of the Pelsart Group. The largest island of the latter group is Pelsart Island itself (called Long Island by the fishermen), an islet of considerable length extending to the extreme south of the Abrolhos archipelago. Although far exceeding all the other islands in length, being roughly eight miles long, Pelsart Island is in most places only a few hundred feet across, and much of this consists of heaped coral fragments. The Pelsart Group takes much more closely than any of the other groups the form of an atoll, a somewhat triangular atoll, with the apex directed towards the south. Pelsart Island forms part of one side of this triangle. A distinct resemblance is to be traced in the Easter Group to the atoll, but this question will be considered in detail when describing the structure of the different islands.

Saville Kent stated that all the islands of the Houtman's Abrolhos were coral formations with the exception of certain of the Wallaby Group. In this region plutonic rocks were said to occur corresponding to those of the mainland and having an elevation of some 30 or 40 feet. It is difficult to understand to what particular rocks Kent referred, but in any case his remarks are incorrect. The Wallaby Islands were carefully examined and, although they are much larger than the other islets and attain the greatest elevation, there is no trace of any rock other than recent limestone. All the Abrolhos islets are coral formations.

The nearest rock of Kent's plutonic type on the mainland is granite. This has been met with in Geraldton at a depth of 420 feet and it also occurs down the coast. It may be pointed out here that Michaelsen and Hartmeyer in their introductory section to the 'Fauna Südwest-Australiens' speak of the coastal limestone near Fremantle as being uplifted coral-reef. This is also quite incorrect, and it is curious that these German workers failed to notice it. The limestone of the Fremantle coast has been formed by the action of water on vast accumulations of drift sand containing much calcium carbonate. The uplifted coral limestone of the Abrolhos is quite different from this æolian limestone of the more southern coast.

The Abrolhos Islands are favourite nesting places of sea-birds, the chief breeding season being about the months of October and November. During these months enormous numbers of Noddy Terns, Sooty Terns, and Lesser Noddies frequent certain islets and the bushes are covered with their nests. They rise in hundreds as one passes across the islets, although many stop in their nests and refuse to budge unless pushed off. Wherever the coral surface is covered with deposits of sand, etc. the excavations of Mutton-birds abound. One falls through into them at every other step. As might well be imagined, vast accumulations of guano have been formed on the Abrolhos and this was removed on a large scale in the early nineties. Wooden jetties were built and long trackways put down on the Wallaby Islands. Moderately sized vessels called for the fertiliser, which was shipped out of the State. Up to 1898 the records show that 55,000 tons of guano had been excavated and exported. The work is still carried on during the summer months by Mr. Fallowfield of Geraldton, who has the concession from the Government for this purpose, but the amount now shifted is small indeed compared with that of earlier days and it is not allowed to be exported out of the State. The guano deposits have covered the coral surfaces of the islands with a layer a foot or more in thickness. The first step in the process of collecting consists in the removal of all plant-growths from the area being worked. Large loose coral blocks are then picked out of it and stacked, and the rest is shovelled away and screened so that all the small stones are removed. The residue is trucked to the jetty and bagged for shipment to the coast. When the guano deposits are removed in this way, the material is stripped so that the limestone surface of the island is exposed. This is often quite flat and smooth, for the action of the rain, the guano deposits, and the coral has resulted in a compact and rather hard surface limestone. The appearance of such an island afterwards is often curious. The surface is brushed clean of all sand and deposit, whilst walls appear to have been constructed in all directions—they represent the stacked coral blocks picked out of the guano.

The invasion of the islands by guano workers has had an appreciable effect upon the land flora, which consists almost entirely of xerophytic and halophytic shrubs, and many of the plants have been introduced from the mainland. So far as the fauna is concerned the guano workers do not seem to have affected it very much, if at all, except that rats became a plague on Rat Island and cats were introduced to keep down the pest. The rats no longer exist, but a few cats occur in a wild state and probably have a very happy time during the nesting season of the terns.

In concluding this brief general description, it may be pointed out that any expedition visiting the Abrolhos Islands has not only to carry full supplies of provisions, but also fresh water. All the water used by the guano workers has to be carried in tanks from Geraldton and is then laboriously bailed out with kerosene tins and stored in small tanks. In the rainy season (winter months July–September) there may be enough rain water, but rain which has fallen heavily whilst I have been on the islands has speedily disappeared. One or two wells occur on the larger islands—East and West Wallaby Isles, Rat Island and Pelsart Island, but the water is poor and brackish and often contains too much decaying organic matter to be pleasant.

METEOROLOGICAL AND HYDROGRAPHICAL CONDITIONS.

Records of sea temperatures are very badly wanted on the coast of Western Australia and up to date but little is known. It would seem strange that the Meteorological Department, although so desirous of forecasting weather, has not arranged long ago to take sea temperatures at their coastal stations, especially where these are only a few yards from the sea. What data I have included here has been obtained from a few records made on our expedition and from the work of Mr. J. J. East of Perth. This gentleman collected the sea temperatures recorded by the engine-room staffs on mail and coastal steamers in Australian waters. The temperatures apply to the sea water as pumped into the condensers. Unfortunately this source of our knowledge only covers a period of a few months and goes but little way to fill up a big gap. The results so far are quite interesting.

From the appended table it will be seen that the coast of Western Australia is washed by water the temperature of which ranges from about 15·6° C.–19·4° C., on the south, to 23·3° C.–30·5° on the north-west. The seasonal change at most places is not very great, and the highest sea temperatures are recorded in February and March, the lowest in August and September.

Sea Temperatures (°C.) *

observed in the offing along the West Coast of Australia (chiefly based on the engine-room log of S.S. 'Paroo' during the years 1908–12, voyaging between Fremantle and Singapore, and various coasting steamers, 1912).

	Jan.	*Feb.*	*Mar.*	*Apl.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
Derby	..	..	30·0	28·9	27·8	25·9	25·6	25·9	25·6	..	..	30·0
Broome	30·7	30·0	30·0	29·8	27·7	24·7	24·8	24·4	23·3	24·4	28·3	29·4
Hedland......	29·4	30·0	29·7	27·8	26·7	24·6	22·5	22·7	22·7	25·3	27·2	28·6
Cossack	28·3	29·6	27·8	28·9	27·2	22·5	22·7	21·4	22·7	24·6	26·1	27·2
Onslow	26·8	28·4	28·2	28·6	26·7	22·4	22·9	21·8	23·3	24·4	23·8	27·8
Carnarvon	24·4	25·6	25·9	25·2	24·9	22·5	22·2	20·8	20·6	21·7	21·7	23·3
Geraldton	22·26	23·6	23·7	23·3	21·8	21·4	20·4	19·7	19·5	19·5	20·4	22·7
Fremantle .... (10–30 miles N. of port)	22·2	22·7	23·3	22·5	20·3	20·8	18·9	17·1	17·8	19·5	20·0	21·9
Albany	..	..	..	..	..	19·0	17·8	16·0	..	..	..	..

NOTE.—Except in the case of Fremantle, the figures are the mean of the observations taken during the watch (10–40 miles run) after leaving, or when approaching, the port named.—Our own temperature observations taken with certificated thermometers indicate that the winter sea temperature at Geraldton is lower than that given in the above table, and the above figures must be taken therefore as only approximate. [W. J. D.]

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* I am indebted to Mr. J. J. East of Perth for the compilation of this table.

At Geraldton, the nearest port to the Abrolhos and in the same latitude as the islands, the sea temperature ranges from about 16·7° C. in winter to 23·5° C. in the summer.

[For purposes of comparison the air temperatures taken in the shade at Geraldton during the three years 1913, 1914, and 1915 are appended. I am indebted to the Commonwealth Meteorological Bureau for this information.]

Shade Temperatures at Geraldton in °F.

	Year.	*Jan.*	*Feb.*	*Mar.*	*Apl.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
Mean max.	1913.	83·9	85·6	83·2	78·7	78·9	72·6	68·7	67·9	72·9	72·5	70·4	77·5
Highest ..		99·3	106·5	107·2	94·6	90·0	82·0	80·0	74·2	95·0	86·1	104·0	103·8
Mean min.		64·5	66·8	65·1	61·0	55·5	55·6	48·6	51·7	51·0	55·5	58·6	62·9
Lowest ..		56·0	54·3	54·5	51·4	47·0	47·0	37·3	43·0	39·0	46·3	47·0	52·8
Mean max.	1914.	85·0	83·3	82·6	75·1	72·6	71·0	67·6	73·2	76·7	77·0	77·1	79·6
Highest ..		109·8	108·3	105·8	84·0	89·8	83·8	74·2	84·0	95·0	97·8	95·0	101·8
Mean min.		65·6	64·3	62·6	56·3	52·2	51·5	50·0	52·0	53·8	60·6	62·5	65·0
Lowest ..		57·5	54·5	47·0	44·0	40·8	43·0	39·0	43·0	42·0	49·0	53·0	55·4
Mean max.	1915.	86·3	84·4	84·0	82·7	76·0	71·4	68·5	69·4	67·8	72·9	81·9	86·6
Highest ..		100·0	106·8	99·0	97·2	84·8	81·8	74·6	78·3	69·8	96·0	104·6	113·0
Mean min.		69·3	69·0	64·1	64·2	58·5	58·3	54·5	54·4	53·5	56·3	61·0	66·0
Lowest ..		59·0	60·8	54·2	53·0	50·8	53·0	41·6	42·0	46·2	46·0	51·0	54·6

If sea temperatures are taken a few miles away from the coast in the region between Geraldton and Shark's Bay, it will be found that these off-shore waters are somewhat warmer than those close to shore in the same latitude.

Now this is an important point, for statements have been made to the effect that the marine fauna of the Abrolhos Islands contains so much of a tropical element that one must travel up to the Tropic of Capricorn before reaching a similar fauna on the coast. Whether this be correct or not [*], the fact remains that the Abrolhos are coral islets, and no coral reefs are met with on the coast for many miles north of this latitude. The statements about the tropical character of the Abrolhos fauna were first put forward by Saville Kent, after his very short stay at the islands in 1894. He suggested also as an explanation that an ocean current existed which set in from the equatorial waters of the Indian Ocean and brought down floating larvæ without impinging on the adjacent coast. In support of this, Kent stated that temperatures as low as 56° F. (13·3° C.) were recorded at Geraldton when at the same time the temperatures at the Abrolhos were 14° *F. higher* (21·1° C.). This is a very considerable difference—14° F. between two places 40 miles apart with oceanic conditions prevailing—and it is a great pity that Kent did not give more details concerning his figures.

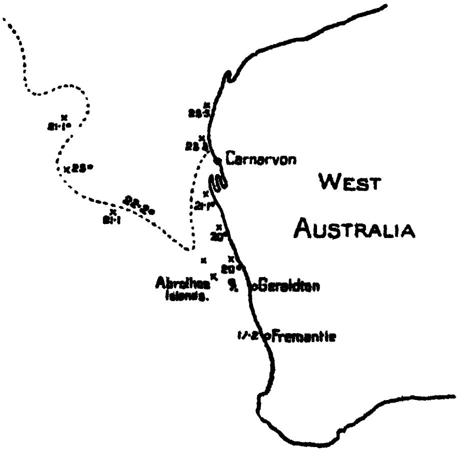
[*] According to Mr. Alexander, who has just completed an account of the Fishes from the Abrolhos, the greater number of species are distinctly Southern types (extratropical forms).

On our first expedition to the Abrolhos, leaving Geraldton on November 9th, 1913, the temperature of the sea at Geraldton was 16·7° C. when we started. On our arrival at the islands we found the temperature to be 20° C. Arrangements had been made for the Harbour Master to take some temperatures at Geraldton whilst we were at the islands. The following is a comparison of the figures, the temperatures being taken at the same hour and early in the morning at the two places.

		Geraldton.		Abrolhos Isles.
Nov. 9th, 1913	...	16·7° C.	...	20° C.
„ 10th, „	...	16·7° C.	...	20° C.
„ 12th, „	...	17·8° C.	...	19·75° C.
„ 13th, „	...	19·4° C.	...	20° C.
„ 15th, „	...	19·4° C.	...	21° C.

The temperatures at Geraldton were certainly lower than those at the Abrolhos Isles, but a remarkable increase happened to take place within a week at the former place whilst the sea temperatures at the islands remained constant. This was undoubtedly due to a very local heat-wave which visited the mainland causing the temperature to rise to 104° F. in the shade! It would quite easily affect the waters of the Geraldton bay. I am afraid this illustrates the futility of drawing conclusions from isolated records. At the same time the early temperatures record a difference of about 3° C. between the waters bathing the Abrolhos and those of Geraldton. This is not such a great difference as that noted by Kent, and I am inclined to regard the low temperature of 13·3° C. recorded by him at Geraldton in July 1894 as also abnormal (granting the possibility of error in making the record).

Text-figure 3.



Further information is, however, to be obtained from the engine-room observations already referred to. If isotherms are plotted from the readings of June 1911, it will be seen that a definite tongue of warmer water extends down the coast of West Australia, the tip reaching to about the Abrolhos Islands (text-fig. 3). During this time, a southern movement of equatorial water was taking place, and it was separated from the coast by a distinct zone of cold water which was still more obvious during the following month and extended from the Leeuwin northwards.

The evidence so far collected goes to show, then, that there is a general tendency for the temperature of the sea at the Abrolhos to be slightly higher than that at the coast, or at all events for certain periods, and that an equatorial current may account for the phenomenon. The difference between the Abrolhos Islands and the mainland may not however lie in the same direction at all seasons of the year. It is to my mind noteworthy that it is during the winter that we are sure of a certain higher degree at the Abrolhos than at Geraldton, and it is not the actual amount of difference that I regard as important but the fact that the temperature at the Abrolhos Islands is pulled up during the winter months, when it probably rarely falls below 20° C. Indications of a tropical current reaching the Abrolhos in the manner described, do not appear on the American Pilot Charts of the Indian Ocean, but the following quotation from Otto Krümmel's 'Oceanographie,' 2te. Aufl. ii. 675–6 (1911), shows that other investigators have noticed these West Australian conditions.

"Im Vergleich zur homologen Benguelaströmung ist die westaustralische nicht durch die gleichen niedrigen Temperaturen an ihrem Küstenrande ausgezeichnet, wie wir sie oben darlegen konnten. Wir haben als Ursache dieses Verhaltens die abweichende Konfiguration des australischen Festlands zu bezeichnen, welche einem von Norden und Nordosten her kommenden warmen Strom entlang der Küste einen Weg nach Süden und somit in den Rücken des Südostpassats gestattet. Dadurch ist also eine ausreichende Kompensation an der Oberfläche von Norden wie von Süden her ermöglicht; man kann schon aus dem Auftreten von Riffkorallen dei den Houttmanischen (28½° S.B.) auf dauernd warmes Wasser schliessen. Ein warmer Strom kommt insbesondere im Südsommer aus der Timorsee und, in den Buchten Nordwestaustraliens Neerströme entwickelnd, geht er nach Südwesten, um anscheinend bei der Dirk-Hartoginsel, dem westlichsten Punkte des Festlandes, nach Süden umzubiegen und nach dem Befund der Gazelle-Expedition 16 Seemeilen in 24 Stunden nach Südosten zu laufen."

We have seen that Saville Kent emphasized the fact that the marine fauna of the Abrolhos differed in an extraordinary manner from that of the adjacent coasts, and he accounted for this by the assumption of a current, the existence of which is now supported by a considerable amount of evidence. The Hamburg Expedition of Michaelsen and Hartmeyer did not visit the

Abrolhos Islands; but Michaelsen adds a note concerning them in a report [*], apparently as a result of an examination of collections in the West Australian Museum. His report is somewhat singular for he makes no reference to the only marine biologist who had visited the islands, and adds: "An exact description of these islets and of their physiographic faunal relations has been given by Helms. After studying the zoological materials of the Abrolhos in the West Australian Museum in Perth, I can affirm Helms' assertion about the marine fauna of the Abrolhos." Now, the first mention of the tropical character of the marine fauna of the Abrolhos is due to Saville Kent. Helms states that this naturalist visited the islands but does not refer to his paper, and indeed does not enter into any discussion on the character of the marine fauna or on the southern position of these islands. Yet Michaelsen states that he can support the remarks of Helms on the character of the marine fauna, and then goes on to account for the tropical character of this fauna. His explanation includes an exactly similar theory to that propounded ten years before by Kent. This is put forward without even the temperature records that Kent had made, and without reference to Admiralty Charts for confirmation. We must consider in some detail the further remarks of Michaelsen to the effect that a "Kalter Auftrieb" rising from the depths of the sea may also explain the difference between the marine fauna of the Abrolhos and the coast.

The term "Kalter Auftrieb" is used by the German hydrographers to denote the rising cold waters which are met with along a lee shore, and are due to the removal of the more superficial waters to windward. This phenomenon accounts very well in many places for a great difference in temperature between the coastal waters and those some little distance out, and excellent examples are to be met with in the Baltic Sea and the Sea of Azof, as well as along the coasts of some continents when strong offshore winds are blowing. This vertically moving colder water is also held to account for the lower sea temperatures in the Atlantic and Pacific Oceans along the Western coasts of Africa and South America in the region of the trade winds, one of the results of which is the well-known absence of coral reefs along the West coasts of these continents.

If, however, we examine the following diagram (text-fig. 4), which shows the position of certain isotherms between the land masses of Australia, South America, and South Africa, we shall see that there is a difference between the west coast of Australia and that of these other two continents.

"The inflowing and outflowing waters probably find their way not only through the wide and deep channels between the islets, but to some extent through the body of the reef, which in its upper portions would appear to be almost as open and pervious as a sponge."—*Judd.* "Materials sent from

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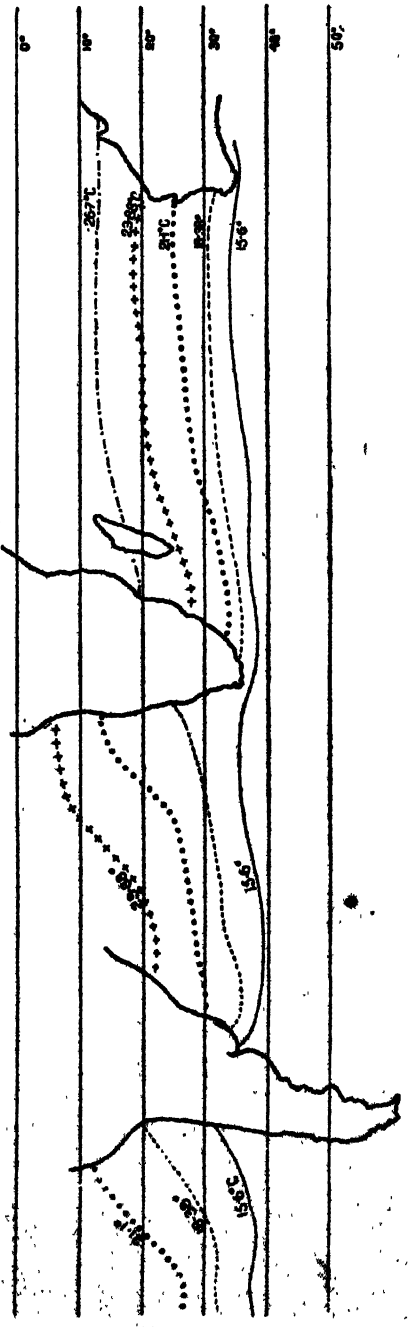
[*] "Die Tierwelt Südwest-Australiens und ihre geographische Berichtegen." Mitteil. Geog. Ges. Hamburg, Bd. xxii.

Funafuti." Report of Coral Reef Committee of the Royal Society, Section X. p. 176 (1904).



Text-figure 4.

The mean annual surface temperature of 21·1° C. is much nearer the equator on the west coasts of South America and South Africa than it is on the west coast of Australia. In other words, the water washing the coast of West Australia is warmer than that washing the west coasts of South America and South Africa in the same latitude.

We really require much more data from this coast before theorising on the effect of such movement of water as a "Kalter Auftrieb." It would appear, however, from the following that Michaelsen's suggestions can scarcely hold good for the region under discussion. East winds are stated to prevail on the west coast of West Australia for a considerable part of each day. "These push the warmer surface water seaward, and so cause the rising of the colder bottom water to replace the driven water at the surface. The rising of the colder bottom water, 'the cold swell,' takes place quite close to the coast and of course influences mostly the line of the coast and its fauna. On the surface the originally colder water soon gets a higher temperature, so that by the time it has been driven by the east winds over the space between the coast and the Abrolhos it has grown warm." We shall refer later to the winds on this coast; let us look again at the sea temperatures. If a cold water upwelling, especially of any extent, takes place along the west coast of Australia it is caused by the trade winds (not an offshore local breeze), and it would probably occur along the edge of the continental shelf and *not* against the coast. The water between the Abrolhos and the mainland is only about 20–25 fathoms deep. Now it is hardly likely that one would find on this shallow coastal strip of water lying over the shelf a much colder zone nearer the bottom consisting of water running in towards the land with a well marked layer of warmer water running out on the surface. The temperatures, so far taken by me, give no indication of such a state, the waters of the shelf appearing homothermic. It must be remembered that there is frequently a considerable sea running in this region, and with depths of only 20 fathoms it is likely that homothermic water will result.

The following figures are taken from those of the last Abrolhos Expedition. Unfortunately they are few because we were usually close to the islands working the lagoons or else to the leeside (the East).

Thursday, 28th October, between Wallaby and Easter Groups towards open ocean.

Surface ...	20·6° C.
15 fathoms ...	19·87° C.

Sunday, November 7th, between Easter Groups and Pelsart Group.

Surface ...	20·8° C.
20 fathoms ...	20·3° C.

Friday, October 22nd, outside Easter Group.

Surface ...	19·8° C.
Bottom ...	19·5° C.

Many readings were taken in the lagoons, but they are useless from the above point of view—the surface and bottom temperatures were usually the same except that the extreme surface layer, on an absolutely calm day, was often higher as a result of the direct heating effects of the sun.

If we examine the prevailing winds at the Abrolhos we shall see that there is less evidence still in favour of a warm surface current blown out from the coast accounting for the Abrolhos Fauna.

Winds, Geraldton District and Abrolhos.

Summer—From the middle of September to the middle of May, Southerly winds are characteristic.

Rest of Year—Winds variable, with occasional N.W. to W. gales of moderate force and of usually short duration.

Summer Winds—During the summer the Southerly wind blows almost without a break and resembles the trade wind in character and in force. In the early hours of the morning it is certainly in the form of a land breeze, but is E.S.E. to S.E. and is light. About 9 a.m. it hauls to the S. or S.S.W. and commences to freshen, blowing its strongest during the afternoon and continuing very frequently until after midnight. It then falls light and works back to the land breeze again. Very occasionally, during the summer, the wind with a falling barometer comes away fresh from the E. to N.E. at sunrise, but it drops at noon and is followed by the Southerly as usual.

Winter Winds—During the winter the winds are variable. Southerly winds are frequent though of lighter force than those during the summer. N.E. winds are also of frequent occurrence in the mornings, but there is a calm or Southerly during the afternoon, or perhaps a strong N.W. blow. Taken altogether there is far less wind during the winter than summer.

Now, at the Abrolhos, 30 to 50 miles away from land, the winds are much the same, except that the land breeze *is not nearly so evident and often quite absent.* There is not much support here for a prevailing East wind blowing out the surface water. Further information may be obtained from actual observations of the currents. Here again I have had to depend upon information culled from the fishermen who are out at all seasons of the year. They state that during the winter, a southerly current is usually experienced between Geraldton and the Islands. Its velocity is about one knot per hour, but this may be increased with N. winds to 2–3 knots. This is quite in favour of the tropical current theory. During the summer southerly set has also been experienced, but as calms are very seldom it has not been noticed nearly so definitely.

TIDES.

The tides on the West Coast of Australia present some great problems, and very little is known of these phenomena at present, although the question is of importance to shipping. For the greater part of the coast from the Leeuwin northwards (as far as Shark's Bay), the rise and fall of the tide is very small, the mean spring rise being only 2 ft. 6 ins. at Fremantle and Geraldton, and only 2 feet at Bunbury. At Carnarvon the mean spring rise is 5 feet, but in the north-west the conditions are very different, and a mean spring rise of 34 feet has been recorded at Derby.

The mean neap rise at Geraldton is only 1 ft. 6 ins.

It must not be thought, however, that tidal phenomena on this coast are only peculiar in that the amplitude varies enormously along the coast, and is so small at Fremantle and Geraldton as to be practically insignificant. The greatest problem is associated with tidal irregularity. Thus, at Fremantle the tides are usually diurnal, roughly 24 hours elapsing between the two high tides. Occasionally, however, for a succession of a few days, the tides become semi-diurnal. The diurnal tides are associated with irregularity, and it is extremely difficult to predict them with any accuracy.

At the Abrolhos, as at Fremantle, there is but little rise and fall of the tide, but it is of more use for collecting purposes than at the latter place, and seems to be of somewhat greater amplitude. We should say that the mean spring rise was nearer three than two feet. On both occasions when we were at the islands the tides were diurnal, and it came as a surprise on our first expedition to find that not only was there but one tide every 24 hours, but that low water came at practically the same hour each day. On both expeditions low water occurred always between 6 and 8 a.m. The harbour master at Geraldton stated that during the summer months the tide at that port was usually high about 9 p.m., with low water at 9 a.m., whilst in the winter the converse was the case. Whether this be so or not at the Abrolhos is impossible to say. We can only affirm that all our shore-collecting was carried out in the early hours of the morning during the last week of October and the month of November.

Stokes gives the following rather surprising details which we can neither confirm nor deny; such conditions certainly did not prevail whilst we were at the islands. The high-water at full moon and change occurred at 6 p.m. During the night there was a short flood lasting six hours, the water rising seven inches, and a shorter ebb of only two hours' duration, the tide falling five inches. During the day, however, there was a flow of 8 hours 20 min., and an ebb of 8 hours 5 min., the rise and fall being 25 and 26 inches respectively. There were further variations at the different island groups. It appears quite certain that the tides are very irregular.

RAINFALL.

No statistics exist, or are likely to exist in the future, concerning the rainfall at the Abrolhos Islands. The nearest figures that can be utilised are those for Geraldton, they will suffice to show the type of rainfall experienced in this region. The rainfall is stated in "points," 100 points equalling an inch.

Rainfall at Geraldton.

Year.	*Jan.*	*Feb.*	*Mar.*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Total.*
1913	30	3	17	107	24	246	367	631	268	118	7	8	1826
1914	3	3	Nil	29	113	291	273	185	5	87	93	Nil	1032
1915	18	459	28	78	241	790	529	332	159	97	Nil	18	2749
Averages for the last 38 years.	16	27	33	87	272	454	392	301	135	66	25	13	1821

NOTE.—The figures indicate "points," one hundred points of rain equal 1 inch.

It will be seen that the average annual rainfall for the last 38 years is 18 inches. The dry months are October, November, December, January, February, and March, the average fall recorded for this period of six months being only 1·8 inches.

NORTH ISLAND.

North Island was only visited on our first expedition to the Abrolhos, and our observations have not been so detailed there as at the other places. This island does not appear to have been visited so frequently as the others, being due in all probability to its greater distance from the coast.

North Island is almost a square mile in area. It is not surrounded by smaller islets, and differs from the other groups we shall consider, in being without any real lagoon region. In fact, the part above water at all states of the tide rises from a coral flat which fringes it on all sides, but it is very much wider on the west than on the east. On the Eastern shore, a fringing reef lies quite close to the island, and a few breaks or channels occur where fishing luggers can obtain some shelter and anchorage in bad weather. The channels, which are very irregular, are about 5–6 fathoms in depth, with sandy bottoms on which large holothurians may be easily seen through the clear water. On the West side of North Island the margin of the reef lies just over a mile away from the shores of the island. No boat channel or lagoon exists between it and the shore. A broad reef-flat extends from the shore out to the reef-margin and is covered by a foot or two of water at high tide. One can walk out for the whole distance, but care must be taken, for the coral surface is rotten and full of holes, with larger hollows here and there. There are no living corals growing upon the surface of this flat. The same reef-flat extends north and south of the island for a greater distance and is continued as a submerged reef for a considerable stretch towards the Wallaby Islands.

The surface of the flat is covered with living *Vermetus*, and, as a matter of fact, this gasteropod is the common animal of all the reef-flats of this region. The shells puncture neat but exceedingly painful holes if anyone carelessly places an unbooted foot on such ground. The rock-pools swarm with young fish which must pass through their larval stages with some rapidity in such heated water (the temperature rises to remarkable points whilst the sun is shining). A blue crab, *Thalamita* sp. (probably *stimpsoni*, an Indian form), was very abundant in holes in this coral, and also the sea-urchin *Echinometra mathæ*. We shall meet with this species elsewhere.

North Island itself and the two large islands of the Wallaby Group are the only ones to attain any height above 8–14 feet. The highest point on North Island is 42 feet above sea-level. All this high ground of North Island consists of blown sand, which rises in the form of dunes quite close to the eastern shore margin. Other hills lie irregularly behind these, so that a distinctly high region occurs close to the eastern side. The height of the island falls off rapidly as the centre is approached. At the south-eastern corner of the island the margin takes the form of a low coral-limestone cliff instead of sand-hills, and the coral-reef flat, already referred to above, runs into the foot of this. As a matter of fact, in many places it is undercut by the sea and overhangs very considerably (Pl. 14. fig. 6). This limestone conglomerate forms the margin of the island for a little distance along the western shore, but gives place to a sandy beach again as the northern shore is reached. The sand dunes are not so high here as on the eastern side. The coral limestone, which is exposed at certain places along the shore, can be traced inland and evidently forms the foundation of the island. Its surface is about 6 or 8 feet above sea-level, and it agrees in structure with that to be referred to later in connection with the Wallaby Isles. The central part of the island is quite low and flat, and only a few feet above sea-level (a salt lake, dried up at the time of our visit, occupies part of it). No rock exposures are visible once the shore is left, the whole being covered with sand which, as we have remarked above, is responsible for the height of the island above sea-level. The sand-hills are thickly covered with low halophytic bushes of a hard and brittle nature, and the terrestrial fauna appears to be poorer than that of the southern islands. The lack of fresh water is probably responsible for this.

Shore-collecting was not very successful at North Island, and as the other islands appeared likely to offer better opportunities for all-round work we spent very little time there. A number of specimens of *Heterodontus phillipi* were captured whilst we lay at anchor close to the shore, together with the Parrot fish (*Coris auricularis*, one of the Labridæ); Groper (*Acherodus gouldii*) ; Skipjack (*Caranx platessa*) and Buffalo Bream (Carangidæ). The latter looks very much finer than it tastes! A number of birds were noted and are enumerated in Mr. Alexander's report. Further reference will be made to the structure of North Island in the section dealing with the formation of the four islands. We may remark here that the wide expanse of reef-flat represents the result of erosion and that North Island will probably be cut down still further in the future.

THE WALLABY ISLES.

This group of coral islets is, in some ways, the most interesting of all, for it is on certain of these that the land fauna requires, as an explanation of its character, the assumption of land connection with the mainland of Australia. The group consists of two large islands (the East and West Wallaby Islands) together with a considerable number of small islets, many of which are not depicted at all on the small-scale charts. The East Wallaby Island lies really north-east of West Wallaby Island, from which it is separated by a very shallow channel about a mile across.

At first sight it appeared somewhat difficult to piece out the former history and the structure of the irregular collection of islands, reefs and lagoons of the Wallaby Group. It became much more clear after our second expedition, and I now consider that the group represents a stage in the development of an atoll form.

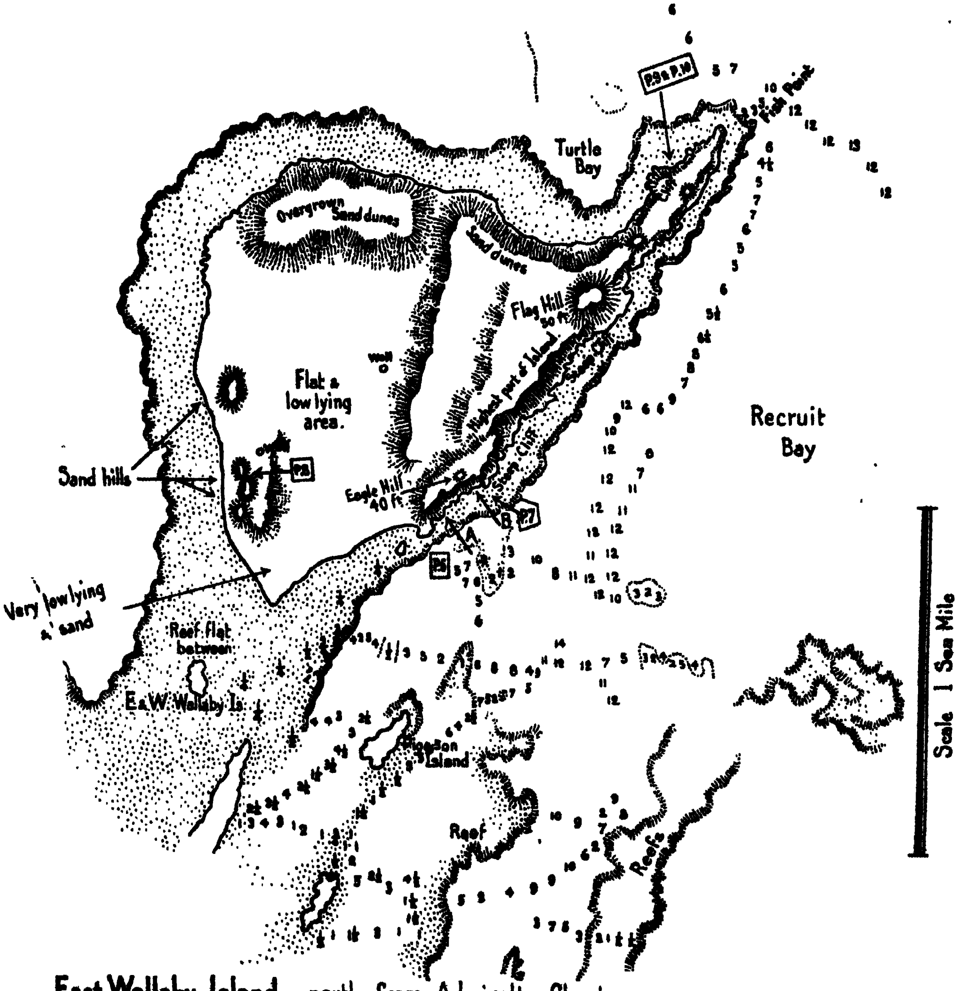
The two large islands form a kind of central mass. To the west of them lies a more or less shallow lagoon with an outer reef margin four miles or so to the west of East Wallaby Isle. To the eastward of the two Wallaby Isles is another lagoon with irregular coral reef bounding it, and small islets exist here and there where the reef rises above the sea-level. When sailing from the coast, one first sights the small islets of the reef on the eastern side, especially the rather long narrow islet (known as Long Island). The elevation of the Wallaby Islands, however, is sufficient to make them more conspicuous than is the case with any of the southern groups, so that in reality they are picked up from the masthead practically as soon as their eastern outposts. On our first expedition we ran into Turtle Bay (see map, text-fig. 5) first, as this shelter was easily reached from the open sea. After a few days we moved down Recruit Bay until a position was reached close to East Wallaby Island and almost opposite the channel between it and West Wallaby Island. On the second expedition we reached the Wallaby Group from the south, and after passing through the Channel close to the east side of Long Island (see map, text-fig. 2) we entered the lagoon and anchored close to the latter. Later on we changed to an anchorage of the former expedition in order to investigate the larger islands over again. Dredging was carried out north of the Wallaby Group between the East Wallaby and North Islands, in Recruit Bay, in the Channel east of Long Island, north of Morning Reef, in the lagoon, and some distance south of the group.

We shall consider the large islands first. The East and West Wallaby Islands appear to have been only recently separated, and the separation does not amount to much at the present time. The channel between them, which has a width of about a mile, is only a foot or so deep at high tide, and large areas are exposed at low water. It was regularly crossed by members of the party when they wished to reach West Wallaby Island, and if the tide were up and one were near the middle of the channel, with a fresh breeze stirring up the water, the situation was distinctly peculiar—one seemed to be standing in the centre of the sea! The floor of the channel is a flat of coral, here and there covered with a thin layer of mud, and bearing very distinct evidence of solution and erosion by the sea. The only additions are being made in odd places by the ever-present *Vermetus*. Beyond a few sponges, crabs, and some fish which abound in the large hollows of the flat, little is flourishing here.

EAST WALLABY ISLAND.

The East Wallaby Island is about 1¼ miles from north to south and a little more from east to west measured along the northern coast. Its longest diameter runs N.E. to S.W. and juts out considerably in the form of a north-eastern cape, Fish Point, which separates Turtle Bay from Recruit Bay. The highest part of East Wallaby Island is 40–50 feet high and this occurs right on the eastern coast, which is of some little elevation from the north-eastern extremity down to a point where it turns more abruptly westward toward the entrance to the Wallaby Channel. By walking along the beach (which is a reef-flat) one can obtain a view of an excellent section showing the structure of the island where its height is greatest (see photo, Pl. 13, fig. 4).

Text-figure 5.



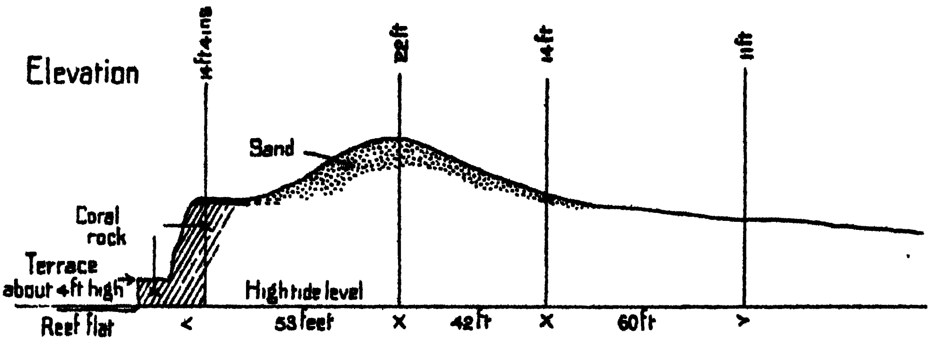
East Wallaby Island. partly from Admiralty Chart.
Reef flat area dotted.
A & B. indicate position of Sections illustrated (Figs. 6 & 7).
Spots photographed indicated by letter P. & fig. no.

(Not all of the Photographs have been reproduced; those numbered 8 and 9 are now 4 and 5 on Plate 13.)

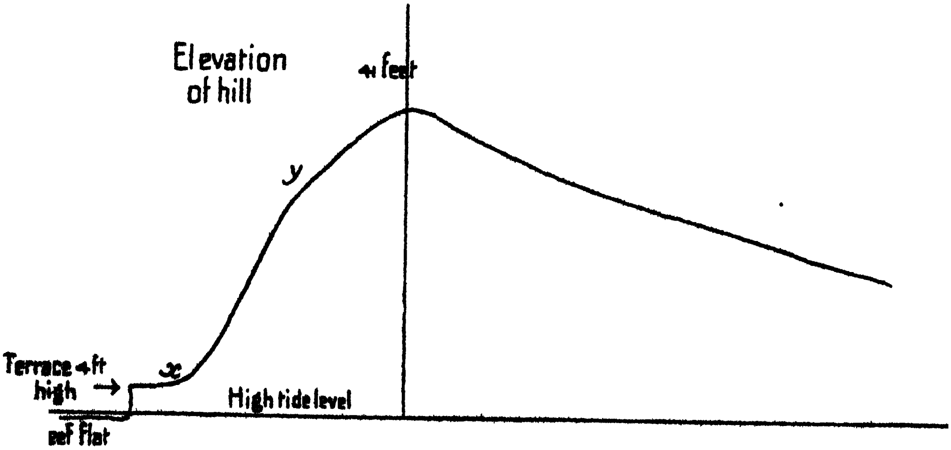
The two text-figures (text-figs. 6 and 7) indicate sections at right angles to the line of coastal cliff. They were taken about a ½ mile apart. A coral-limestone cliff rises direct from the reef-flat and overhangs somewhat.

It is washed by the sea at high tide. This cliff is only from 4–7 feet high and presents a flat terrace of varying width, here only a foot or so, there a couple of yards (see text-figs.). From this, another cliff-surface rises to a varying height, 14 feet in the one case shown above, to probably upwards of 25 feet in the other. This is marked by another limestone surface, and it is possible to notice from the sea how this surface is not at the same height along the stretch of coast, but varies slightly. The complete height of 22 feet in the one section and 40 feet in the other is brought about by sand. On East Wallaby Island there is nowhere a thickness of 40 feet of coral above sea-level. Fourteen to twenty feet is probably about the maximum, and this is topped with sand. This condition, however, exists only along the margin of the East coast which runs in a straight line N.E.–S.W. If a traverse is made inland in a westerly direction (see map of East Wallaby Island, p. 151) the sand-hills become lower, until at a distance varying from $\frac{1}{4}$–$\frac{1}{2}$ a mile inland they disappear, and one reaches an almost perfectly flat area the

Text-figure 6.



Text-figure 7.



surface of which is limestone. No sand or guano hides the rock in this area now, but a few bushes are rooted in the crevices and cracks in the weathered limestone surface. This flat area occupies the greater part of East Wallaby Island, and sand-hills are not met with again until one reaches the extreme west and northern coasts. It might be expected that the flat area we have described with the coral-limestone surface would be as many feet above sea-level as the highest limestone exposed on the East coast. This is not the case, it is only about 10 feet above sea-level. It is only on the East coast of East Wallaby Island that any limestone higher than this is found. At the same time, the land rises once more on the western margin, so that the greatest heights are found on the East *and* West coasts. If, however, the eastern elevations are examined, they will be found to be composed entirely of sand, and the exposures are quite interesting. One of these eastern sand-hills is marked on the chart with an elevation of 35 feet—a well is indicated about 200 yards to the N.E. of it. Now just north of this sand-hill the wind has cut an extraordinary pass right through the hills and eroded it down to the limestone surface. The sides of the pass are perfectly vertical and there is abundant evidence that the whole is due to the wind. It is quite obvious here that the high land is due chiefly to blown sand.

The southern extremity of East Wallaby Island towards the channel is the lowest part of the island, and a sand-beach presents a marked contrast to the cliffs of the eastern shore. This sandy beach extends up the western shore to the north-western corner of the island where cliffs again appear, but only 3–4 feet in height and have a sandy beach at their base. The northern beaches are also of sand, with sand-hills behind, until Fish Point is reached on the east of Turtle Bay. Samples of the shore-sand from the north and west beaches of East Wallaby Island have been examined. The sand consists almost entirely of calcareous matter:—foraminifera, shell-fragments, coral particles, and echinoid spines. The foraminifera are all shallow-water forms, the predominant genera being *Orbitolites*, *Polystomella*, and *Peneroplis*. Other common forms are species of *Miliolina*, *Planorbulina*, *Globigerina*, and *Pulvinulina*.

A reef-flat exists all round the island, but it presents some points of difference on the various coasts. On the east coast (Recruit Bay), it is narrow, 100–200 feet or so in width, and extends to the base of the limestone cliff. It is covered with living *Vermetus*, and broken up with irregular hollows every here and there. To the south it forms a great expanse connecting East Wallaby Island with West Wallaby Island. On the west of the island the reef-flat is wider and extends out for at least a quarter of a mile from the beach, which, as we have already noted, is of sand. The same aspect presents itself again on the north-west, and there is much sand and weed growths here. A considerable quantity of decaying weed is conspicuous on the eastern and northern shores.

Let us return to the limestone. The best exposures illustrating its structure are to be seen in Turtle Bay on the west side of Fish Point (Pl. 10). The cliff is collapsing here, but the surface is not weathered in the same way as at some other places where its structure is hidden. The limestone is a conglomerate of coral and mollusc shells (Pl. 10). In parts it has quite a stratified appearance due to the presence of great flat coral colonies of a species common at present in the lagoons and allied to *Madrepora corymbosa*, if not this species itself. Between the corals is a hard mass of coral-mud, or secondary deposits of calcium carbonate, which cement everything together, and in which lamellibranch and gasteropod shells are imbedded. These shells show little or no signs of weathering or of abrasion. (See photo, Pl. 10.) The most common of the molluscs are

Turbo pulcher, Reeve.
Conus magus, Linn.
Cytherea reticulata, Linn.
Septifer bilocularis, Linn.

There is every evidence of elevation to bring this coral limestone into its present position, and the corals appear for the most part to have grown *in situ*. We shall refer to this elevation later after describing West Wallaby Island.

It has been said that plutonic rocks occur on the Wallaby Islands. We have now made traverses across these islands in every direction, and we have also closely examined the wells which occur in one or two places. Nothing but limestone is to be seen anywhere, and we are quite sure that this rock only is present. There are no references to the actual discovery, or examination, of plutonic rock in the literature on the islands. What statements are made appear to be due to a casual remark which has been handed on by people who have not investigated, and in some cases not even visited, the islands.

WEST WALLABY ISLAND.

There is no need to describe in any detail the structure of West Wallaby Island, for it is clearly the same as East Wallaby Island and obviously part of the same elevated limestone mass. West Wallaby Island is of irregular shape and is the largest island of the Abrolhos. From north to south the greatest length is just short of three miles. A few points of interest should be noted. The highest part of West Wallaby Island does *not* occur on the eastern side (*cf.* East Wallaby Isle), but on the southern mile of the western coast, and this elevated region is remarkably like that already described as occurring on the N.E. coast of East Wallaby Island. The highest point, for example, is again quite close to the shore, and a steep cliff rises at once from the reef-flat. The cliffs themselves rise to a height of 30 feet, and the greatest elevation, only a little distance inland from these, is upwards of 50 feet.

This south-western corner of West Wallaby Island presents the finest scenic picture of the Abrolhos Islands, the cliffs are of rugged weathered limestone, and the margin of the outer reef swings in at this place until it comes quite close to the extreme S.W. point. The full swell of the ocean breaks, therefore, quite close to the island, and the waves rush across the reef-flat wearing deep pot-holes and excavating the coast. The photographs illustrate the type of coast at this point (Pl. **14**. fig. 7).

It is very interesting to note that the mile of coast on the south-western shore of the island should resemble closely the stretch on the north-east of East Wallaby Island. Everywhere else on the Wallaby Islands the margin is much lower and with either sand or low-lying limestone.

Another point of great interest on the West Wallaby Island is the occurrence of a well-marked terrace on the western cliffs, about 6–8 feet above the level of the reef-flat. A similar terrace, slightly lower in places, is found, as already stated, on the N.E. shore of East Wallaby Island. We shall see later that there is evidence on the Abrolhos Islands of a recent uplift of 8 feet or so. The terrace represents the old sea-level before the last elevation.

A considerable part of the area of the West Wallaby Island is low-lying, being about 6 feet above sea-level. This applies to all the north-eastern portion (about a square mile) and the southern part of the East coast. The north-eastern region presents a surface which is largely flat limestone—resembling in appearance that photographed by Fryer on Picard Island in the Indian Ocean and described as "platin." It is covered with the usual stunted halophytic bush. In most places the limestone is completely hidden by a layer of guano and sand which looks as if inhabited by thousands of rabbits. The excavations are, however, due to mutton-birds, and as they are not very deep it is usual for anyone trying to walk over this area to fall through with one foot or both at every other step! The pavement-like surface of the limestone has been probably produced by successive solutions and redepositions of calcium carbonate by rain-water—the guano aiding. In past times a large quantity of guano was removed from West Wallaby Island and the ruins of an old camp and about 1¼ miles of tramway still exist as relics, whilst a wooden pier runs out for a considerable distance on the west coast into the waters of the lagoon.

We devoted some little attention to the limestone exposed on West Wallaby Island, especially on the West coast where there was a thickness of 25–30 feet above sea-level. The lowest parts at this place consist of a compact rock, granular in appearance, fairly hard and without any traces of corals or molluscs. Microscopic examinations, kindly carried out for me by Professor Woolnough, of the University of West Australia, reveal the fact that it is entirely composed of Foraminifera, Nullipore fragments, and Echinoderm spines, with a considerable amount of secondary deposition of carbonates round the individual grains. It is in fact an indurated beach-formation. No trace of land-derived sediment exists. It is this rock which forms the lowest part of the cliff, a layer of coral rock infiltrated with secondary carbonates appears at a higher level.

A reef-flat extends round the base of the West Wallaby Island. On the eastern side it extends out for some distance and smaller islets rise from it. This area will be dealt with again below. To the south the flat is narrow, and lies close up against the outer reef at this point. On the south-western side, at the foot of the high cliffs already described, the reef-flat is wide again, and here one meets with plenty of evidence showing that the flat has been formed by erosion. Pinnacles of rock are left standing, overhanging on every side (Pl. **14.** fig. 7), and great pot-holes occur on the flat itself.

THE REEF AND SMALLER ISLETS OF THE WALLABY GROUP.

It is convenient after discussing the character of the chief land masses of the Wallaby Group to consider as a whole the remaining small islets and the coral reefs surrounding them. The "tout ensemble" is much more irregular than in the southern groups to be presently considered. A glance at the chart (text-fig. 2, p. 136) will show that a mass of coral reef exists several miles to the west of West Wallaby Island and protects a lagoon with 3–4 fathoms as an average depth in the northern portion. Towards the south-western point of West Wallaby Island this reef swings in, until it joins the reef-flat which fringes both the Wallaby Islands and forms the inner shore of the lagoon. Towards the same point, the broad lagoon becomes more and more shallow until only one or two feet in depth. The outer reef, against which the ocean swell beats, remains close to the coast of West Wallaby Island on the south as a fringing reef, and then leaves the S.E. point of the island in the form of another broad sweep which extends eastwards, but in a more irregular manner, and can be traced past Noon Reef and Morning Reef, where it turns northerly (text-fig. 2, p. 136). Inside the large expanse sheltered by the reef there are numerous coral growths and remains of islands, the whole thing being the result of solution, denudation, and active coral growth.

The two Wallaby Islands are connected, as we have already pointed out, by a broad and shallow reef-flat. This reef-flat extends over the shaded area in text-fig. 2, and several small islands rise from it, three of which (the more northerly ones) are shown on the map of East Wallaby Island (text-fig. 5, p. 151). The most northerly of these is called Pigeon Island by the fishermen, who like to enter Recruit Bay as far as they can and anchor with perfect shelter between Pigeon Island and East Wallaby. We camped on it several times. All the islands on this reef-flat agree in type. They are usually much longer than broad and with the long axis running nearly north and south. They are all flat-topped, and possess vertical or overhanging cliffs about 8 feet in height (they are highest on Pigeon Island, 8–10 feet). Again, there is ample evidence that they have once been continuous. Pigeon Island is gradually becoming smaller, the cliffs overhanging in places for 20 feet or so forming caverns. Here and there great masses have broken off and are gradually being removed. The structure of the coral limestone of which they are composed is similar to that of the Wallaby Islands.

Whilst a glimpse of these islands with the lagoon waters presents certain pleasing features, they make a very uninteresting photograph. No palms or tall plants break the monotony, and the elevation of the islands is so small that from a little distance they appear simply as streaks in a photograph.

It may be taken for granted that all these islets have been cut away from one mass, and they are still being reduced in size by the action of the sea. The reef-flat connecting them together is all that remains of the elevated limestone of which they once formed part.

We are now left with one or two islets much further away from the Wallaby Islands on the outer reefs to the east, a narrow island known as Long Island by the fishermen and several islets not marked on the chart, some of which are only a few yards across. Many of these islands are obviously the result of blocks of coral heaped up by the waves, and their loose structure is quite different from the more compact limestone of the central mass. We are in fact dealing with structures more like the islets of the rim of a coral atoll.

Let us glance at Long Island, it being the largest islet in this situation. It is about one mile long and only a few hundred feet across. Its surface consists of small and loose coral fragments, and in fact the whole island is made up of such coral fragments. They prevail above all else, and one cannot consider coral as playing any subordinate part here to calcareous algæ, molluscs, or other calcareous structures in the formation of this mass. In places, the weathered fragments have been more or less cemented together to form a more definite kind of conglomerate. I consider that a slight elevation (not more than 6 feet) has played some part in the formation of Long Island as well as the heaping up of the coral fragments by the waves. The straight line taken by the reef on which the land stands is no doubt due to the current, which scours the eastern side, and has produced the channel referred to later.

A small lake exists at the northern extremity of the island and there are one or two other similar depressions at other places. We shall see that these are quite common on the islets of the rim of the Abrolhos Groups. This is rather an interesting point, and I have found it very advantageous and informing to compare the descriptions given by Stanley Gardiner of the "faros" of the Maldives with these islands of the outer rim possessing lakes or lagoonlets. The water of the lakes is salt, and often disappears altogether at low tide. In other cases it is permanently present, and deep, but rises and falls with the tide outside. One in Long Island is only a few yards across, the banks are of coral conglomerate and loose blocks, and the floor of the lake or lagoonlet of coral with a deposit of mud. We shall refer in greater detail to the formation of these lakes when describing the same on the islets of the Easter Group.

Mention must be made here of the channel to the east of Long Island. It is very much used by fishing boats passing north and south, for it has a depth of 20 fathoms, and that quite close to Long Island itself. The channel seems to have broken through the reef, cutting off Morning Reef to the east of it from the coral masses on the west. Perhaps Long Island itself owes its formation to the development of this channel. As one would expect from the depth, a strong scour runs through the channel which bears every appearance of erosion. We dredged several times here and with excellent results.

Nothing more remains to be said about the reefs except that coral growth is active at the present time in the lagoons wherever the water appears to be free from mud. To the north-west of the coral marked Noon Reef on the chart is an expanse of water almost completely surrounded by coral reef. It can be entered by a channel to the west of Long Island, and by another one to the S.W. indicated by the arrow on the map, text-fig. 2, p. 136. This expanse of water is called "The Lagoon" by the fishermen (no other area is spoken of as lagoon by the fishermen anywhere in the Abrolhos Group). Depths of 6–12 fathoms occur, and the bottom is almost everywhere of coral. We investigated this area with the motor dinghy on many occasions, and were always delighted with the gorgeous growths of coral seen perfectly through the clear water. The most abundant coral is a species of *Madrepora* with a most beautiful blue-purple colour. This occurs everywhere, rising from the bottom in the form of great "shrubs." The more compact corals like *Meandrina* and *Astræa*, etc., do not seem to flourish here. *Pocillopora* is common in places. We have never obtained a *Fungia* at any of the Abrolhos Islands, and have seen no traces of such, not even fragments. Several times we tried the dredge in these lagoons and pulled it forcibly over the bottom, tearing away the more delicate corals at the risk of losing the dredge and cable, but we never obtained anything but coral and the small crustacea and worms which live in the crevices.

It would seem to us that the outer margins of the coral reefs fringing the Wallaby Group are extending seawards by active coral growth, at least in places, but that such growth is very slow. In the lagoons we see coral growth in certain areas, and sandy deposits with no coral growth in other parts. Here active solution and erosion is taking place, whilst there we find that coral growths are forming, or coral fragments are being heaped up by currents and wave action. In the latter case small islets are formed and are often capped with a little sand. They only rise perhaps one foot above high-tide mark and are known by the fishermen as "Sandy Islands."

THE FAUNA OF THE WALLABY GROUP.

The name of the group suggests the first member of the fauna that deserves mention. The Wallaby *Macropus eugenii*, Desm., occurs on both East and West Wallaby Islands and in very large numbers, especially on the West Wallaby Island. I have seen far more individuals in one afternoon at these islands than of all species of marsupials seen on the mainland in three years! Some surprise was exhibited last year when I stated that four were shot on our first expedition without moving from the one place—one shot having killed two. On our second expedition we beat this by actually catching four specimens alive, by merely running them down! It is no uncommon sight to see half a dozen leaping before one at the same time. Naturally it is a point of the greatest interest to find fifty miles away from the coast, on a small coral island with only halophytic bushes, an animal of this kind in such large numbers. The large Wallaby Islands are the only ones inhabited by a marsupial. Traces of other mammals also occur, and a much decomposed rat was found (and left) in one of the water-holes on West Wallaby Island. Reptiles abound on these islands and were even common on the smaller ones which we have already referred to as rising from the Wallaby Reef flat. One of the most interesting is the Carpet Snake (*Python spilotes*), which occurs in very large numbers on West Wallaby Island. We could hardly ever walk down the two miles of the old guano tramway on the occasion of our first expedition without meeting several specimens lying across it, and usually they averaged about 7 feet in length. They were very sluggish. Curiously enough we did not see one in 1915; probably they hibernate in winter, and the winter of 1915 was particularly severe and extended well into October. No specimens were met with on any other but the West Wallaby Island. Two other species of snakes are supposed to occur in the Wallaby Isles, one of which was seen but not captured. Reference to the Lacertilia will be made in Mr. Alexander's paper on the Vertebrates. Seventeen species are recorded altogether from the Abrolhos Islands, and probably most of these occur only on the West and East Wallaby Islands. Two or three species are common on the smaller islands of this group, but the larger southern islands of the Pelsart and Easter groups have only one or two. Two species of Amphibia, frogs, are recorded from the islands, but we were unsuccessful on both occasions in finding any. On our second expedition we thought we should be more successful owing to the wet winter and our earlier arrival at the islands. We failed, however, to see any trace of them.

Several species of birds were nesting on the Wallaby Islands, and an account of the species recorded is given in Mr. Alexander's paper. The following remarks may be made here in reference to the photographs taken by the author. A large number of birds had congregated for nesting purposes on the west shore of the West Wallaby Island, several species occurring together. At one place there were several hundred nests of the Pied Cormorant (*Hypoleucus varius hypoleucus*, Brandt), all built of broken twigs and branches from some neighbouring bushes, and erected in close contact on the sandy shore. Our arrival was the signal for the departure of the birds, but the less shy Gulls, undisturbed by our presence, took the opportunity of feasting upon the eggs. Close to the Cormorant colony, Caspian Terns, Pacific Gulls, and Silver Gulls were nesting. The eggs were simply laid in slight hollows in the sand amongst stray pieces of mollusc shells. Reference has already been made to the Mutton-bird excavations. The birds must occur in thousands on the Abrolhos Islands wherever the rock is covered with sand in which they can burrow.

Several species of insects were captured on the islands, but the collection has not yet been worked up. The ant keeps up its West Australian reputation and is present everywhere, on the smallest islands as well as on the larger.

THE MARINE FAUNA OF THE WALLABY GROUP.

The first place to be examined was Turtle Bay on the north of East Wallaby Island. The bottom was for the most part sandy with groves of Algæ, species of *Codium* being particularly abundant. *Zostera* also occurs here in large quantities. Except for a few Amphipods, both Algæ and *Zostera* were very barren. The shore sand contained a large percentage of Foraminifera of which *Orbitolites* was the most common. The very characteristic *Heterostegina* of the Ceylon sands appeared to be absent altogether. Nothing of particular interest was obtained on the reef-flat on the east side of East Wallaby Island. *Vermetus* was very abundant, a few sponges and crustacea occurred, and the coral limestone was bored by *Lithodomus* and Gephyrea. We used our chloride of lime for capturing fish in the rock-pools with some success here, but unfortunately our work was cut short by bad weather which caused so much disturbance of the water on the reef-flat, that it was impossible to poison the fish—they moved with the waves to other pools! Our best shore-collecting was carried out on the lagoon side of a small island (loose coral fragments heaped by waves) on the outer reef, about 1¼ miles to the east of the extreme S.E. point of West Wallaby Island. A long spit composed of small blocks of coral runs out from this island and is entirely submerged at high tide. The lagoon bottom to the north of the island was of sand, but with very fine growths of coral here and there, the two species most abundant being the purple *Madrepora* already mentioned, and tree-fungus-like growths of a species allied to *M. corymbosa*, forming great flat expansions 3–6 feet across. Several large species of Holothurians abounded on the shore of the island, and could be picked up by wading. Anemones, Ascidians, and Sponges (calcareous and siliceous) abounded, and several Turbellaria were captured under the stones. In fact we were able to make a very good general collection here. A better place still on our first expedition was the eastern shore of Long Island. The beach consists of large coral slabs thrown up by the waves, and at low-water mark almost each slab was covered on its under surface with a gorgeous array of organisms. Rarely have I met such variety and colouring. A straggling brilliant lemon-yellow sponge was one very evident specimen. After turning several stones over and noticing what appeared to be pieces of this sponge falling off, it was discovered that the falling pieces were nudibranchs resembling the sponge in both colour and general appearance. The species belongs to the genus *Notodoris*, this being the first record for the genus on the Australian coast. It was instituted by Bergh for a single specimen of *N. citrina* from Rarotonga. Two other species have been made by Eliot for specimens from Zanzibar and the Maldive Islands. All three are yellow in colour. It is stated in Eliot's report that nothing is known of the habits of these animals and further—" With Mr. Gardiner's specimen is a piece of hard yellow sponge. There is no note, but as the colour and consistency of the sponge closely resemble those of the Nudibranch it is highly probable that the latter frequent it."

It is interesting to find that this is actually the case and in an entirely different region. Our specimens were always found associated with the sponge. The Nudibranch moves about very slowly, so far as could be observed, and apparently lives in the dark under coral blocks.

A large number of different species of Brachyura occurred on the Long Island shore, amongst which may be mentioned the characteristic species *Liolphus platissimus*. This peculiarly shaped and beautifully marked crab was exceedingly common. It is an Indian form. Several specimens of the Stomatopod *Gonodactylus chiagra* were also obtained under stones.

Small macrurans of a species as yet not identified were common, and specimens of at least two species of *Alpheus* were captured. The Echinoderm collection contained chiefly large crinoids and asterids. The gorgonids were represented by one species.

On the western shores of West Wallaby Island collections were also made on the reef-flat. Five or six species of anemones were to be seen here in great numbers. The most abundant molluscs were *Astralium* sp., with beautiful blue operculum (the species is common on the coast both north and south of the Abrolhos latitude), and *Vermetus*. Large numbers of the Siphonophore, *Porpita*, came in over the reef one afternoon.

Hauls with the dredge were made several times just outside Recruit Bay, with a depth of 20 fathoms. We finished up to the N.E. with a sandy bottom and an abundance of seaweed. Large hauls of sponges were made here, and compound Ascidians and Echinoderms, including *Synapta* sp., were present in considerable numbers. Echinoderms were always well to the fore so far as individual numbers were concerned. Crustacea were only moderately represented, being chiefly Brachyura and Alpheids, which abounded in the crannies of the coral rocks brought up in the dredge. Macrura were not common on the whole.

A few dredge hauls were made east of Evening Reef in a rather rough sea. The bottom was of sand and small fragments with much weed. A few Echinoderms were obtained, including a fine *Astrophyton.*

THE EASTER GROUP.

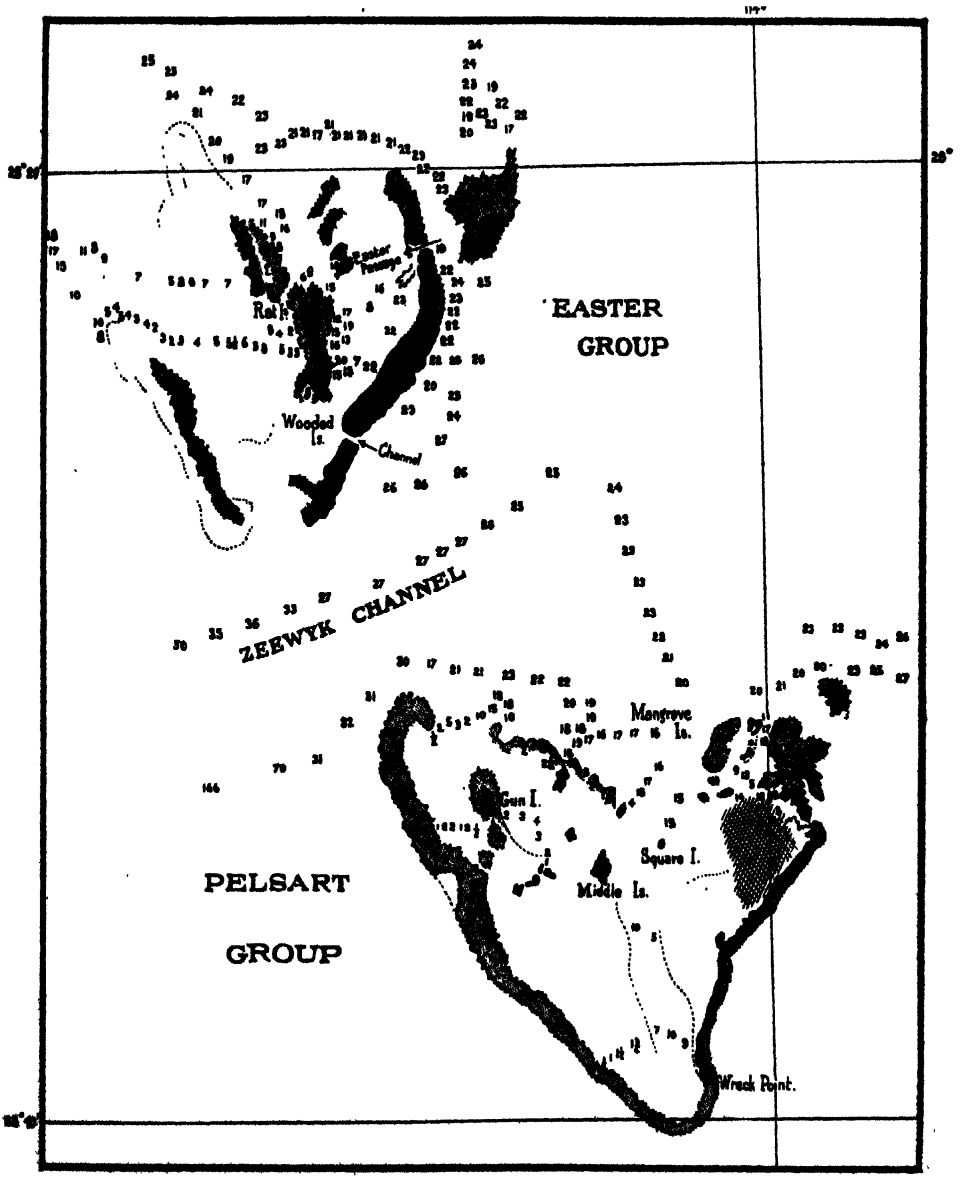
The Easter Group differs in several respects from the group of islets we have just been considering. In the first place it has much more the aspect of an atoll with an island in the middle of the lagoon, the total area of the atoll measuring about 35 square miles.

The central island is Rat Island, (2 or 3 small islets which lie to the south and are separated by narrow channels a few yards across—dry at low tide—may be considered as part of it), and a glance at the chart (text-fig. 8) will show that the surrounding reefs encircle it in quite a regular manner at a distance varying from 2–5 miles. A gap occurs in the reefs to the south of the group, and they are not well developed to the north-west and north. In other words, the larger entrances to the lagoon are to the north and north-west. We shall see later that this agrees with the Pelsart Group. It will be remembered here that encircling reefs were similarly best developed to the south of the Wallaby Group, whilst the chief entrances to the lagoons opened to the north.

The encircling reef to the west of Rat Island does not bear any islets above sea-level at high tide. There are several islets, however, on the eastern rim forming a chain upwards of eight miles in length. This development also agrees perfectly with the character of the more southern group of the Abrolhos. Each group of islets is evidently being modelled by the same forces and conditions. The depths of water in the lagoon of the Easter Group range from 2–22 fathoms, there being quite considerable depths on the eastern side of Rat Island between it and the islands of the rim. Before considering, however, the lagoon and the coral reefs, let us glance at the central islet—Rat Island. This is the largest island of the Easter Group, but it is smaller than either of the two Wallaby Islands, being only a little over ¾ mile long (from N. to S.) and not half a mile broad.

The small islets to the south of Rat Island are four in number and are obviously part of it. They rise from the same reef-flat and show distinct signs of having been cut off comparatively recently by erosion. All agree in formation and in appearance. Rat Island itself is flat-topped and almost everywhere exactly 8 feet high. The margins take the form of an undercut cliff, which overhangs very considerably in most places. Here and there are great masses which have fallen and now are being removed by the sea at

Text-figure 8.

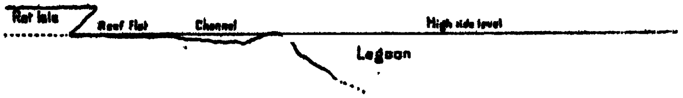


high tide. It has been turned over pretty thoroughly by the guano workers, so that there is little material left over the rock and one can examine the latter quite easily at any point. It is a coral limestone which has been so compacted that a very hard homogeneous mass has been produced. Professor Woolnough, who kindly made sections of this material for me, states that it is coral rock completely infiltrated with secondary carbonates and completely solid. I consider that the coral limestone of the central islets is slightly older than any rocks exposed as part of the outer reef islets.

The surface of the island is covered with the usual bushes standing about four feet high at most. Many introduced plants occur, the result of the residence of guano workers and fishermen. Numerous holes due to subaërial denudation exist, and two or three of these may be termed wells—they probably contain fresh water throughout the year. It is neither satisfactory, nor plentiful enough, for the few guano workers at present on the islands, who have all their supplies brought in tanks from the mainland.

Surrounding the whole of Rat Island is a reef-flat which is increasing in width, for the island is being rapidly eroded to this level. Close to the edge of the reef-flat, just before the deeper waters of the lagoon are reached, is a small boat channel about four feet deep. The section (text-fig. 9) shown illustrates this character.

Text-figure 9.



The rim islands of the Easter Group and the eastern area of the lagoon have been very closely examined—more so than other parts of the Abrolhos. There are upwards of a dozen islets of varying size, some of which can hardly be said to be separated from one another, for at low tide one can cross without wetting the feet, whilst at high tide it is quite easy to wade across. Others are, however, separated by deeper channels.

A channel, with 6–10 fathoms of water, exists where we entered the lagoon of the Easter Group (see chart), called Easter passage by the fishermen. Another one occurs just south of Wooded Island where the charts are marked "Channel reported." Between these two passages there are no deep channels, and one could pass more or less easily from islet to islet, a distance of roughly 5 miles. All these islets agree, as might be expected, in character. They are largely composed of heaped up blocks and fragments of coral. For the greater part these still remain loose and uncemented, or but slightly so. In places, however, a more solid limestone is exposed, as for example on Wooded Island and on the southern end of the islet immediately to the north of it. It is a conglomerate composed chiefly of weathered fragments of coral. The island immediately south of the Easter passage is also largely composed of cemented coral fragments. At no place is the height of these islets of the outer rim as great as that of Rat Island (viz. 8 feet), and, as we have already pointed out, where the land does consist of cemented coral fragments the limestone produced is nothing like so hard or compact as that of Rat Island.

The eastern beaches of the islands in every case consist mainly of loose coral blocks, and in places one can see how these are piled in such a manner as to form very definite strata by the regular heaping of these blocks on the northern shore of Wooded Island.

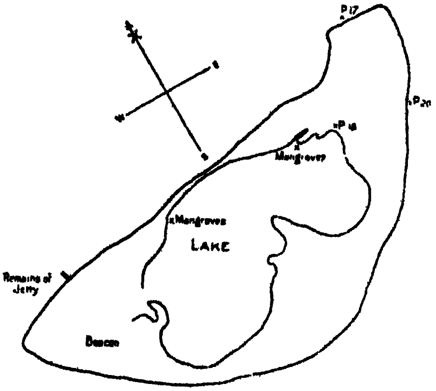
In many places, perhaps in most, the surface of the coral blocks is covered with sand and guano. The surface of Wooded Island appears to be of quite clean coral fragments with a sparse covering of shrubs and *Mesembryanthemum.* I find, however, that the guano workers shifted some tons of guano several years ago from the island, and it is quite probable that they also cleared this material from the general surface.

There is a great tendency towards the formation of small or large lakes on these islands. This has proceeded to such an extent that Wooded Island has quite a character of its own ; a lagoon of such extent exists that the island might be called a miniature atoll. Moreover, this internal lagoon attains a considerable depth, for we sounded six fathoms in the centre. The water of all these hollows, whether small or large, is salt, and furthermore is in communication with the sea. Some idea of the mode of formation of the comparatively large lagoonlet on Wooded Island can be deduced from the smaller ones on the other rim islands. Thus, on the island immediately south of Easter passage is a pit with six feet of water in it at the deepest part. It is 58 feet wide across the widest part and 100 feet long, being roughly oval in shape. The sides of this hollow overhang and are obviously being eroded at the water-level. On one side a large slab of the cemented coral formation has broken off owing to this undercutting. There is ample evidence that these hollows are produced by the combined action of percolating sea-water and the weather, and in most cases *after* the formation of the land. By means of a few simple surveying instruments, we were able to show that the level of the sea-water within the hollow was either the same as that of the sea-water outside the island, or within a foot or so of it. Whilst the tide was rising, the level of the water within the hollow was somewhere about one foot below the sea-level. When the tide was falling, the level of the water within was higher than sea-level by about the same amount. The communication with the sea is therefore evident, and also the "lag" due to the resistance experienced by the percolating water.

Another much larger "lake" existed on the island we have just referred to, but it is not so large as that on Wooded Island. In character it is similar to the one already described, and it is obviously produced by the extension in area of such a small one, or the union of several small ones.

The floor of the hollows referred to on the more northerly island was of hard coral, with a small deposit of calcareous mud. *Ulva* and one or two species of mollusca abound in the water and a fish (a species of Cobbler) was captured in the smaller cavity. It is impossible to say whether these fish could pass in after having attained the size which they measured—7 to 8 inches. They may have reached the interior at a much earlier stage and developed there. In any case they must have passed at some stage through a considerable length of subterranean channel, for it is very unlikely, if not impossible, that human hands could have placed them where they were found.

Text-figure 10.



We have surveyed the rim islet known as Wooded Island and a rough map of the same is given (text-fig. 10) which shows the extent of the remarkable lake or "velu." * Now this velu is of very considerable depth (6 fathoms), and from certain points of difference between it and the smaller ones mentioned, and also from the fact that very similar "holes" exist on the reef-flat in the lagoon close by, I am inclined to believe that this lagoonlet or "velu" had developed before Wooded Island rose above high-tide level. In any case, the original velu has been enlarged since, by erosion similar to that taking place in the smallest pits, and probably guano workers have shifted deposits from it where the mangrove trees are found.

One very frequently finds mangrove trees growing in these hollows—in fact they are restricted to this position on the islands of the outer rim of the Easter Group. Several small thickets occur on the shores of the velu of Wooded Isle, and a thicket occurs in a similar depression (which, however, is without sea-water at any state of tide) on the island immediately north of it. This latter hollow (Pl. 12) has almost been filled up with guano deposits resulting from the hosts of the Lesser Noddy, which breeds only on Wooded Island and the adjacent one. The amount of guano produced by the birds is so great that it is actually causing the death of these mangrove trees on the northerly of the two islets, and quite half the thicket consists of leafless and bleached branches. The nests of the Lesser Noddy are only to be found in the mangrove trees. Since the guano workers meditate an attack on this deposit, and their working months coincide with the breeding season of the birds, it is quite possible that the Lesser Noddy may leave these islands in the future.

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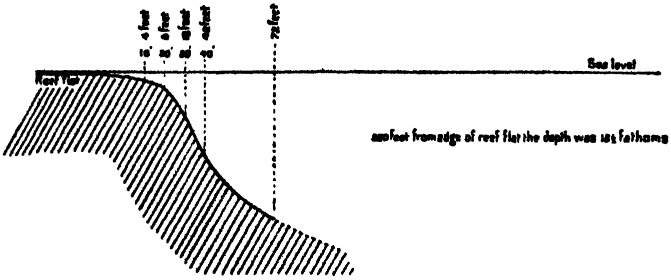
* The term "velu" is used by Stanley Gardiner for the lagoonlets or deep pools sometimes found on the islets of the Maldive atolls. I have not used the term throughout for the hollows referred to above, owing to an uncertainty as to whether it would be correct to apply it here. The lagoonlet on Wooded Island seems, however, to agree both in formation and appearance with the "velus" of the Maldives.

The Lagoon and Submerged Reefs.

The usual reef-flat occurs round the islets of the eastern rim. In fact, this is a continuous structure running at least from Easter passage to the passage south of Wooded Islet, and the islets are only elevations upon it. On the seaward side the reef-flat varies in width, but it has the same character throughout. The surface is fairly smooth, not eroded leaving sharp points, as in some places in the Wallaby Group, where it is more exposed to still water and rain than to the constant wash of the sea at high tide. Large hollows occur here and there, and form shore pools at low tide in which animal life abounds. As a matter of fact, this reef-flat was probably our best shore-collecting ground in the whole of the Abrolhos. On one occasion the sea was calm enough for us to examine the outer margin of the reef from the motor dinghy. At the particular place visited the reef-flat was about 100 feet wide. It rose slightly, not more than a foot, at its extreme margin and then descended to a depth of 15½ fathoms in 100 yards. It was not easy to fix our position and make soundings, being shorthanded, and there was just enough swell to make very careful handling of the boat a necessity, especially when near the edge of the reef-flat; some figures were obtained, however, and the diagram indicates the nature of the slope.

Text-figure 11.



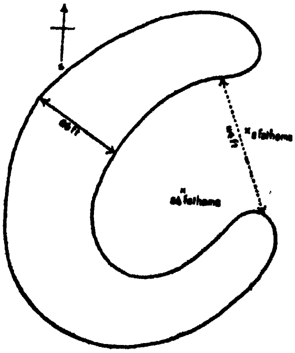
Corals were growing actively on the outer edge, and there is evidence that the reef is extending seawards although but slowly. There are signs that the islands of the outer rim on the eastern side of the Easter Group are becoming joined up. There was certainly a deep channel at one time between Wooded Island and the one immediately north of it. At least I judge so from certain peculiar holes and channels amidst the reefs in the lagoon at this point. Now, one can walk across even at high tide, although if a strong wind blew from the east it might be difficult. We shall see later that in the Pelsart Group, which seems to represent a stage to which the Easter Group is leading, there are very few channels indeed and a single long island forms the eastern rim.

The lagoon reef-flat differed in character from that of the seaward side. In some places it was covered and hidden by sand or mud. In other places it was eroded in such a way as to be honeycombed everywhere, leaving but rotten coral, so that one had to be prepared when walking for at least one's foot going through. This was the case along the lagoon side of Wooded Island. Usually the reef-flat ended with an abrupt drop to the depth of the lagoon, instead of the slope to the sea-bottom which is seen on the outside. In some places, as a matter of fact, it overhangs. There were luxuriant coral growths along the lagoon edge of the reef-flat on the shore of Wooded Island, the more massive corals being present as well as several species of Madrepore, *Pocillopora*, and *Montipora*, but I do not think the reef-flat is extending lagoonwards at this point. Coral growths occur on the floor of the lagoon between Wooded Island and Rat Island, although not very luxuriant, and often nothing but dead fragments come up in the dredge. North of this latter region, *i.e.* between the islets immediately north of Wooded Island and Rat Island, the bottom of the lagoon consists of fine impalpable coral-mud, and dredge hauls were exceedingly barren. Further north still, between Rat Island and the island immediately south of Easter passage, luxuriant growths of coral occur once more, and in many places submerged reefs rise sufficiently high to be a menace to boats drawing 8 feet of water. One of these reefs, situated just to the left after entering the lagoon by the Easter passage, was rather interesting, and some notes may not be out of place here.

The reef in question rises up to the surface so that it is exposed at low tide. It is ring-shaped in form, with a broad opening on one side—that directed N.E. towards the nearest island of the outer rim. The sketch given in the text (fig. 12) indicates roughly the form of the reef, its dimensions, and the depths of water about it.

The bottom of the small enclosed lagoon is about 30 feet deep, and living coral abounds. It is also to be found on the floor of the entrance, and along the outer margins of the reef. It would appear that this structure resembles the "faros" of the Maldive Islands. It has developed by active coral growth from the floor of the lagoon, and it has taken up its present form as a result of natural phenomena related to the growth of reef-building corals. Neither elevation nor subsidence are required to account for it. The only other possible explanation is that this ring-shaped reef is all that remains of a former mass perhaps at one time part of the outer rim islets some distance away from it. In that case erosion would play a more prominent part in the explanation of the present form, but would be governed by phenomena of normal coral growth. One can find other cases in the Pelsart Group where small coral growths are taking the form of miniature atolls, and neither subsidence nor the heaping of debris by waves and currents are responsible for the general architecture of these structures. Just as the one mentioned above occurs where coral growths are most luxuriant in the Easter Group lagoon, *i.e.* near its northern end, so in the Pelsart Group the northern open side of the atoll is the site of the greatest lagoon coral growth. In the latter case it is obvious that the general trend of water in the lagoon is from south to north, and the water is more free from sand and debris to the north where the lagoon is open to the sea.

Text-figure 12.



Faunistic Notes on the Easter Group.

No large mammals occur on Rat Island except those which have been introduced, and mention has already been made of the cat which was introduced by the guano workers to keep down the rats.

The island has been noted by many ornithologists for the vast number of Noddy Terns which are found regularly every year during the months of October and November nesting upon the bushes. The nests are practically nothing but "stations" on the tops of the shrubs where the birds lay their eggs (Pl. 12). Very often one meets with shrubs almost covered with the nests of these birds, the owners refusing to leave them when disturbed, unless actually pushed off. Large numbers of Sooty Terns also nest on this island, but they prefer the ground just below the bushes. They are more timid than the Noddy Terns, and leave their nests on the approach of an intruder.

Mention has already been made of the Lesser Noddy which inhabits the mangrove trees of Wooded Island and the islet to the north of it. In the case of the latter, the mangrove thicket presents a curious appearance at the breeding season. The branches of the trees are covered with picturesque nests of seaweed, the straggling ends of which hang down; the birds are not at all shy, as may be guessed from the photograph (see Pl. 11).

Reptiles are much less common in the Easter Group than on the islands of the Wallaby Group, and no snakes are found. Two small species of lizards were seen on Rat Island but not captured. Rat Island was one of the few places where we were troubled with Diptera—another relic of human occupation.

The reef-flat surrounding Rat Island did not prove to be a very good collecting ground. *Vermetus* was common as usual, and rock pools containing small fish and some crabs and Macrura were abundant. A living specimen of *Physalia* was captured in one of them, having drifted in with the previous high tide. Corals and gorgonids occurred on the submerged blocks of the little jetty which runs out for a few yards on the north of the island. Wooded Island coral flats—both the lagoon and seaward flats—proved extremely interesting, and were the home of a rich shore fauna. The margin of the lagoon flat, which as we have already pointed out presents an almost vertical or overhanging wall dropping to about 10 fathoms of water, is a beautiful picture of coral growth, a considerable number of species occurring side by side. A very large Crinoid lives in enormous numbers amongst these coral growths, and in many cases half a dozen or so could be picked up in a mass. Their colour was a gorgeous mixture of green and yellow, but unfortunately it left the animal's body with the greatest ease on preservation, and coloured everything else a rather dirty brownish green!

Another animal which was extraordinarily abundant on this little stretch of lagoon flat (only on the margin) was a large and beautiful Nudibranch, almost certainly new and allied probably to *Dendronotus*. The singularity of its occurrence is accentuated by the fact that notwithstanding its abundance here, not a specimen was captured anywhere else at the Abrolhos, and on our second visit in 1915 it was just as common at this place as two years before.

Large simple Ascidians and a large species of Serpulidæ were marked features of this reef-margin. On the seaward side several species of Chitonidæ were obtained, *Cryptoplax* sp. being fairly common. Sea-Urchins (chiefly *Echinometra mathæ*) occur in large numbers, each individual in a little hollow in the reef-flat which it has excavated and into which it fits. Nudibranchs and Tectibranchs (*Aplysia* sp.) were extremely common. We could have obtained hundreds of specimens of *Aplysia* by merely picking them up as we waded in the shallow water. Under the larger coral blocks was a rich ascidian and sponge fauna, and one or two cidarids were obtained. Alpheids and other Macrura abound.

Reference must be made also to our dredge hauls. We dredged in the lagoon, but obtained little except on certain patches where we procured several species of Ascidians (simple and compound) not met with elsewhere, and some coral blocks with Brachiopods adhering to them. Against the edge of the reef-flat (lagoon) we obtained little else but fragments of rotten coral, and, as already pointed out, further north we obtained coral mud and nothing else.

In the passage south of Wooded Island the dredge brought up great quantities of weed. We have already referred to the algæ as being common at other places. As a matter of fact, it appears strange to the writer to find so much coral growth and a rich algal flora in close proximity. Unfortunately I have not yet been able to see a coral reef in real tropical waters—the comparison with the Abrolhos would be interesting in many respects. On our last expedition to the Abrolhos we made a good collection of these algæ and they now await examination.

THE PELSART GROUP.

We have emphasized the fact that the Abrolhos Islands are extremely far south for a rich growth of reefs. It is interesting to note that it is the Pelsart Group—the most southern group of the Abrolhos Islets—which most resembles an atoll, and which has given us our best collecting. It is also the historically interesting region of the Abrolhos.

The Pelsart "Group" consists of a more or less triangular lagoon bounded on two sides by a continuous coral reef, and more or less open to the sea on the north. There are three small islets in the lagoon—Gun Island, Middle Island, and Square Island—together with some smaller islets not all properly charted. Deep water is found closer to the encircling reef than to the outer islets of any of the other Abrolhos Groups, and, on the ocean side, depths of over 100 fathoms are quite near, whilst even on the eastern side the depths are at least two or three fathoms greater than to the east of the more northerly islets.

The Western margin of the Pelsart Atoll is formed of a long reef extending for upwards of 14 miles without any breaks, and without any heaping of coral fragments above high-tide level to form islets. This reef rises about one foot so above low-water mark.

On the Eastern side of the Pelsart Lagoon there is a typical rim islet—Pelsart Island. This is the longest in the Abrolhos Group and extends for about eight miles. It is quite narrow, being in some places only a few hundred feet across. At the extreme southern end of Pelsart Island (which runs roughly N.N.E.–S.S.W.) the reef runs S.W. for a little distance, and then curves round to continue in a north-westerly direction as the western part of the encircling reef. Thus, there is no entrance into the lagoon over the encircling reef between the northern extremity of Pelsart Island on the east, and the northern end of the Western Reef (see text-fig. 8). On the North, however, the lagoon is open to the channel between the Pelsart and Easter Groups (the Zeewyk Channel), and the encircling reef is represented by a large number of scattered reefs and islands. There is quite a collection of these at the north-eastern corner of the lagoon (the Mangrove Islands of the Chart). On our second expedition we anchored the lugger amidst these islets and used the motor dinghy for work in the lagoon. On the first expedition we sailed the lugger through the lagoon (beating all the way against the dominant southerly wind) to the southern extremity of Pelsart Island, where we anchored not far from the ruins of a wooden jetty. When still some distance away from the encircling reef one hears the continued thunder of the breaking waves, for the ocean swell comes in unhindered till it meets this coral barrier. One can often see the white breakers when several miles away owing to mirage effects. This effect was noted by Kent, whose observations at the Abrolhos Islands were confined chiefly to the Pelsart Islands, and a half-tone production of a photograph showing these breakers is given in his work 'The Naturalist in Australia' (page 132).

A steady wash of water is apparently the usual occurrence over the southern and south-western part of the encircling reef into the lagoon, and consequently a current of some strength is met with in the latter, the water running from south to north. As a result, the lagoon water to the north is more free from debris than that towards the southern part of the lagoon. This factor determines to a large extent the position of lagoon coral growths.

The lagoon is roughly 11 sea miles across where it is widest, and about 8 miles from north to south. One does not meet with the same depths that are found in the Easter or Wallaby Groups, and over a very considerable part of the area of the lagoon the depth varies round two, three or four fathoms. This applies to the whole of the southern end where the depth is only 6–8 feet, except for a channel which is indicated on the chart and runs S.S.E. towards the southern end of Pelsart Island. In this channel depths round 10 fathoms are recorded. There is a very considerable difference indeed between the floor of the lagoon in different parts. At the southern end it is flat, with a floor of level coral covered with but little sand, except in patches. Probably the current is too strong for deposition of debris except in certain places. No live coral growths were observed here. The bottom of the lagoon near Pelsart Island, and about opposite the middle of its length, is somewhat similar but with a greater deposit of sand. To the north-east of the lagoon (the part shaded on the map, text-fig. 8, between

Square Island and the northern extremity of Pelsart Island), the lagoon is broken up in the most extraordinary way by reefs. The best illustration of their character, that I can think of, is to refer the reader to the well-known "maze" constructed of hedges that one meets with in certain of our famous English gardens. Our attempts to find a way through the lagoon at this place, with the motor dinghy, were absolutely the same as those of an unfortunate stranger in a "maze." The "hedges" of the maze are represented by coral reefs rising vertically from the bottom of the lagoon and having flat tops which stand a little above low-water mark. They are circular, semicircular, straight, and of all manner of shapes. The water between them is often of considerable depth, 13 to 16 fathoms in fact, and one careers along happily for a little distance only to find perhaps a blind end in front. This means a return and another trial along some other channel.

Rich coral growths are found in this north-eastern corner of the lagoon, and, as a matter of fact, this is the only place in the Abrolhos Group where we found fields of Madrepora so close to the surface that they were exposed at very low tide. This observation fits in with Saville Kent's "chromo" made twenty years ago, but Kent did not know that he had pictured about the only spot in the Abrolhos Group where such a growth of coral prevailed.

I am convinced that the greater part of these lagoon reefs in the north-eastern area of the Pelsart Atoll are due directly to coral growth from the bottom of the lagoon, and not to the erosion of an elevated area. Their sides rise almost vertically from the bottom, but growths extend outwards from the top, and frequently overhanging portions break off and fall to the bottom to be overgrown by fresh coral. Wherever coral growth is not taking place one finds erosion, deposition of sand, or a temporary state of equilibrium. The atoll is the result of no single factor, but of a complex interaction of vital, physical, and chemical components.

The larger islets of the lagoon were unfortunately (owing to lack of time) but cursorily examined, but some of the smaller ones on the north were visited several times and Pelsart Island itself was examined more closely. The smaller islets consist of coral rocks and debris heaped up by the waves. Some of those in the north, however, seem to have suffered an elevation of a few feet, and this also applies to Pelsart Island. The coral fragments do not remain loose but are compacted together by secondary deposition. A well near the southern end of Pelsart Island enables one to obtain a glimpse of 10–12 feet of rock, all of which is coral conglomerate. Much of Pelsart Island is composed of loose fragments still, and in some places there are enormous quantities of gastoropod shells which have been thrown up. The island is 6–8 feet above sea-level, and sand and guano deposits occur here and there. Guano workers have, however, visited this island, and consequently the surface deposits have been somewhat tampered with.

Mangroves rise from the lagoon flat at many points on the shore of Pelsart Island, and they also occur on some of the Northern Islets. This coral flat, however, is not to be found forming the lagoon shore of Pelsart Island along its entire length; there are many stretches of sandy beach, the sand forming a covering over the limestone flat.

There remains for further consideration the encircling coral reef to windward of the lagoon. On approaching this barrier at low tide, and from the lagoon, one draws near to a kind of great natural weir over which the ocean water flows almost constantly. The reef is two or three hundred feet across and the surface is smooth and well worn by the water. Few blocks of loose coral are to be found on it and practically no stones to turn over, except where they lie in a hollow—a rock-pool at low tide. Besides these small pools, however, there are large cavities—great pot-holes. Near the lagoon margin in one or two places were also irregular excavations which were perfect pictures at low tide, for amidst the scattered coral growths were long needle-spined echinoids and thousands of fishes—huge Gropers (*Acherodus gouldii*) and other species which probably enjoyed the seclusion of these cavities so well supplied with food. The antennæ of the large Crayfish *Panulirus penicillatus* projected everywhere from the crannies. We have already remarked that there are no islets on the western margin of the atoll. It would appear as if the ocean swell was too powerful to allow any heaping of coral fragments to take place. Broken pieces of coral must be constantly thrown on the reef from the outer face and yet there is no collection of this on the reef itself. The lagoon is noticeably more shallow near this windward side than against Pelsart Island to leeward. Some idea of the force of the waves is apparent from the fact that half the engine-room and some other sections of a ship, the 'Windsor,' now lie littered on this reef not far from the southern extremity of Pelsart Island. They have been picked up from the bottom outside the reef and thrown on top of it.

THE FAUNA OF THE PELSART GROUP.

There is little to add regarding the terrestrial fauna of the islands. As might be expected, it is poorer than that of the islands of the more northern groups. The bird fauna alone is abundant, and many species were found nesting in considerable numbers, including Mutton-birds, Sooty Terns, Noddy Terns, and Ospreys. Beyond a small lizard, which occurred also on Rat Island, no other vertebrates were observed.

The marine fauna, on the other hand, was decidedly interesting. In this connection we may mention certain dredge hauls taken in the Zeewyk Channel just north of the Pelsart Group. The bottom was sandy with lumps of worn nullipore and shells. The dredge brought up hundreds of Holothurians of two or three species, one being particularly common. Large quantities of Cidarids were common at the same place, but there were few star-fish and these practically all Ophiuroidea. In contrast to the hauls at almost all other places, we obtained but few sponges and fewer ascidians.

Our most interesting finds were obtained by shore-collecting on the outer reef, starting from the southern extreme end of Pelsart Island and working south and west. At this spot we obtained the first specimens of any Enteropneust to be recorded from the West coast of Australia. They were found in the coarse sand which lies in a few places, sheltered in shallow hollows on the reef-flat close to the lagoon. On both expeditions we obtained them by sifting the sand through the fingers, and nowhere else but here on the Pelsart Reef were we successful in finding any. The animals were translucent and of a pale yellow colour. They varied in size, one of the larger specimens measuring 12 centimetres when somewhat contracted. After fixation very great contraction takes place and dimensions of fixed specimens are of little value. The species has been described by the author in another paper, and is regarded as a new species of the genus *Ptychodera* allied to *P. flava*. It has been called *Ptychodera pelsarti* after the famous voyager whose ship was wrecked on the group now bearing his name *.

On the same reef, in close proximity to the spot where *Ptychodera* occurs, we found a large species of Pagurid particularly common—each shell bearing three or four large anemones. The gephyrean *Bonellia* was found for the first time on the coast of West Australia. It has since turned up several times on the coast, off Fremantle, but the species has not yet been investigated.

The Pelsart Atoll seems to be a particularly happy ground for Echinodermata. Several species of Echini occur on the floor of the lagoon, each occupying its own area. A very fine species, resembling the English *Echinus esculentus* in size, occurs in immense numbers on the floor of the lagoon at the southern end of the atoll. In another region not far from this we passed over large numbers of Asterids. Very few Alcyonaria have been obtained from the Abrolhos, and so far as our collections go these were all obtained on the Pelsart Group. Some were collected on the reef near its extreme southern point, whilst others were abundant on the northern shores of the islets termed the Mangrove Islands on the chart.

Some of these islands, together with the coral reefs, form a small well-sheltered area known by the fishermen as Whale's Bay. It is entered by a narrow channel from the north, and, as it is quite close to the open sea and in a very suitable position for departures to Geraldton, it is well frequented by the fishermen, who anchor there for the night. I was informed that the spot was well known to the fishermen as a place to which whales resorted to scrape off their attached barnacles. The skipper of our lugger said that they had on more than one occasion had a whale scraping itself against the anchor chain. I was rather sceptical at first about these stories, but am quite certain now that whales do resort to this small enclosed area for this purpose, for we had visitors whilst I was there. As it is not easy to find the entrance, and the area is but small, any other good reason for the frequency of whales in this particular spot seems to me entirely wanting. The visitors whilst we were there were specimens of the Humpback.

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* Journ. Linn. Soc., Zool. xxxiii. (1916) pp. 85-100, pls. 10, 11.

A detailed report on the general faunistic characters of the Abrolhos Islands will be written up after the various collections have been investigated by specialists.

CONCLUSION.

The Coral Formations of the Abrolhos Islands.

It will be convenient if our observations on the coral reefs of the Abrolhos Archipelago are brought together in the form of a theory relating to the origin of these islands.

To this end it will be advisable in the first place to repeat in summarised form certain observations that have been made. They are as follows:—

1. The islands consist entirely of limestones for the greater part composed of recent corals cemented together by secondary deposits of carbonates. In places, as, for example, the lowest rock exposures on West Wallaby Island, the limestone consists of foraminifera, echinoid spine fragments, and nullipore fragments, cemented together by secondary carbonates into a compact rock. The corals and molluscs are all recent and shallow-water species.

No signs of any plutonic rock, or other rock older than the limestone mentioned above, are to be found.

2. The more northerly islands, *i. e.*, the large central islands of the Wallaby Group, show signs of considerable elevation, cliffs of limestone rising to heights of 30 feet. The islands of the southern groups are not nearly so high.

3. All the island groups show evidence of a more recent elevation of about 8 feet. This is marked by the terrace on the East and West Wallaby Islands, and by the uniform flat worn surface of other islands which rise to about the height of this terrace, *i.e.*, Rat Island, some parts of Wooded Island, Gun Island, Pelsart Island (part), and some of the Mangrove Islands.

4. The most southern group of the Abrolhos Islands, the Pelsart Group, takes the form of an atoll. The lagoon depths are moderate, 17 fathoms being the greatest recorded, and the depths on the outside of the encircling reef are not very great, averaging probably about 30 fathoms, but not less on the west side where the depths are considerable a few miles away. This absence of depth is due to the fact that the atoll rises from the continental shelf, which is uniformly level over a considerable area. Had this sea-bottom sloped more rapidly, there is no doubt that the outward growth of the

encircling reefs with talus formation would have resulted in greater depths on the western side of the encircling reef.

In this connection it is worthy of note that Darwin in an appendix to his famous work, 'Coral Reefs,' p. 230, refers to the Abrolhos, about which it is true he had very little information, in the following terms:—

"Houtman's Abrolhos (lat. 28° S. on west coast) have lately been surveyed by Captain Wickham (as described in Naut. Mag. 1841, p. 440) . . . . . From the extreme irregularity of these reefs with their lagoons, and from their position on a bank, the usual depth of which is only 30 fathoms, I have not ventured to class them with atolls, and hence have left them uncoloured."*

The reefs of the Pelsart Atoll cannot be said to be arranged irregularly, and the fact that the islands rise from a bank is no reason against terming any of the groups an atoll, unless we argue that every atoll must be formed according to Darwin's views.

5. I consider that the Wallaby and Easter Groups represent stages in the formation of such a type as the so-called Pelsart Group. Easter Group, for example, can be compared with an atoll having still a large island in the centre of the lagoon. The Wallaby Group is least like an atoll and consists of a group of islets, the remains of a large limestone mass, surrounded by irregularly arranged reefs. North Island is still practically only an elevated limestone topped with sand dunes and rising from a reef-flat which extends seawards. Lagoon formation is only commencing on its eastern side, and encircling reefs cannot be said to exist. It is possible that North Island will develop along the lines indicated by the other groups.

There are several interesting points of resemblance between the Wallaby, Easter, and Pelsart Groups. In the first place, the large openings into the lagoons are always found to the north. This is the only way into the Pelsart Atoll. Both the other groups can be entered from the south, but careful navigation of the channels is required. We find a long rim islet without a break, in the Pelsart Group, and we have noticed that there is evidence of confluence of the rim islets in the Easter Group to bring about a similar condition. More primitive conditions prevail in the Wallaby Group and the rim islets are not even regularly placed. It will be noticed that rim islets are developing on the eastern, the leeward, side *in each group*.

6. Judging from the presence of certain elements in the fauna of the Wallaby Islands—the Wallabies, and the Amphibia—it is extremely probable that land connection existed between the mainland of Australia and this part of the Abrolhos Group at least.

The foundation of the Abrolhos Groups is probably Tertiary limestone, but of this we have no very direct evidence. It is worthy of note, that north of the Abrolhos Islands the sea is deeper at a similar distance from the coast. In other words, the Abrolhos Islands rise from a bank connected with the coast. We must start therefore from the stage when limestones formed largely of corals, foraminifera, mollusca, and calcareous algæ were elevated in this region and united to the mainland of Australia. In fact, the west coast of Australia may be said to have been brought much further west.

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* Uncoloured on the map given by Darwin.

This elevated limestone was weathered and eroded, and it is very likely that the channels between the present groups of islands bear some relation to the presence of small rivers, the Hutt River, the Bowes River, and the Chapman River, opening on the adjacent coast. During this period the Wallabies and Amphibia inhabited the extreme western region of the coast now represented by the East and West Wallaby Islands.

This period of elevation was followed by one of depression or subsidence, and of this there is ample evidence on the present West Australian coast. Jutson* states: "In the vicinity of Perth the coast-line was formerly farther west, as indicated by the drowned valley of the Swan River." Further examples occur in the south-west and also to the north. Thus the same author states, "The North coast is the most broken in West Australia. Deep sounds and bays run far into the land, and are manifestly the drowned continuations of the adjacent rivers. This region has been deeply dissected, probably to maturity, and then submerged. It thus affords excellent illustrations of drowned valleys."

This subsidence may be considered to have separated the Abrolhos Islands from the mainland. It is also possible that a fault running approximately N. and S. occurs between the islands and the mainland, and has helped to bring about separation, for there are several faults running parallel with the coast in this region. In any case subsidence together with erosion resulted in the separation of probably four land masses from the mainland, the ancestors of the present four groups.

We have now four islands of coral limestone, and we may assume that either the altitude of the more northern ones was higher than that of the others before subsidence, or else that the subsidence was not uniform and the southern island was depressed most. This is to account for the much greater altitude of the Wallaby Isles to-day.

Around the original islands encircling reefs have developed, whilst at the same time erosion has taken place and tended to remove them, lagoons taking their place. Such erosion has produced least effect so far in the Wallaby and North Island Groups, probably owing to their greater elevation to start with. Evidence of this erosion is everywhere present. The East and West Wallaby Islands have been separated, and a series of small islets to the east of them are all remnants of the original central mass. An excellent

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* Jutson. "An Outline of the Physiography of Western Australia." Bull. 61. Geol. Surv. West. Australia. Perth, 1914.

LIMESTONE CLIFF, TURTLE BAY.

LESSER NODDY NESTING ON MANGROVES.

NODDY TERNS.

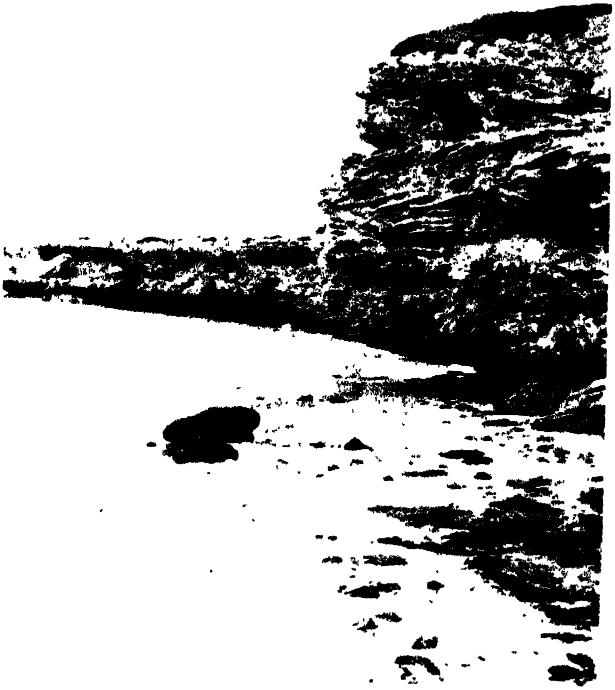

FIG. 4.

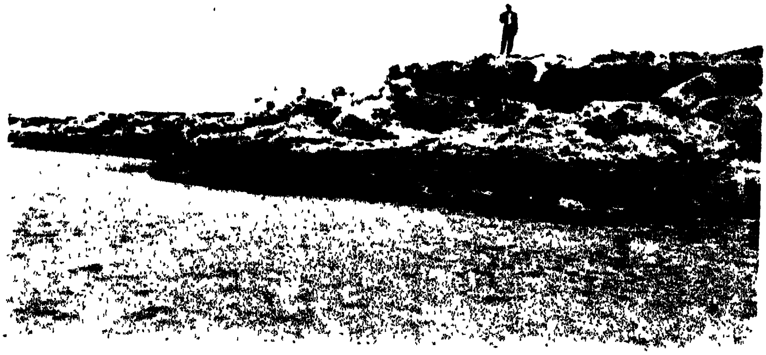

FIG. 5.

ABROLHOS ISLANDS.

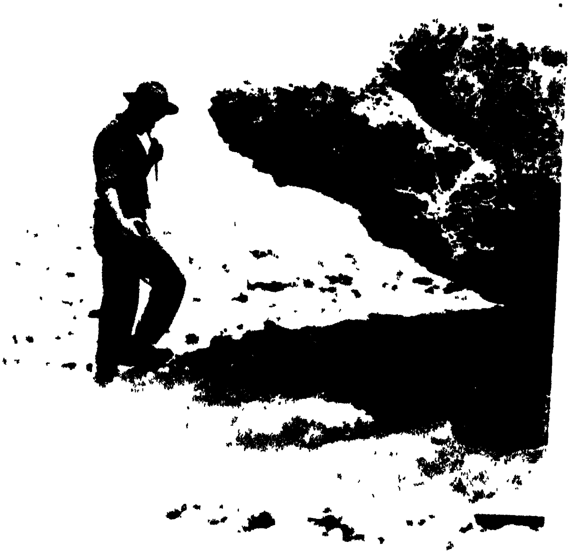

FIG. 6.

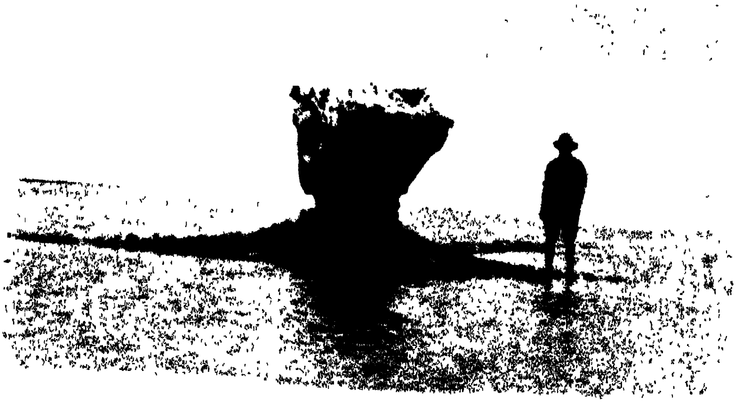

FIG. 7.

ABROLHOS ISLANDS.

illustration of this erosion is left on the reef-flat to the west of West Wallaby Island and is depicted (Plate 14. fig. 7). It consists of a limestone mass which overhangs on all sides, and agrees entirely in structure with the rock of the adjacent island a few hundred feet away. A few more years and it also will have gone.

Erosion has done much more in the Easter Group, where the original central mass is now represented by Rat Island. The lagoon is deep, particularly on the eastern side, and there are several islets on the encircling reef to the east, of which Wooded Island is an excellent example. These islands consist for the greater part of heaped coral fragments, loose or cemented into a conglomerate, and very frequently lagoonlets are present on them.

In the Pelsart Group the central mass is now represented by only small islets, and they are few in number. The outer reef is much more regular than in the other groups, and is practically unbroken on two sides.

So far, we have emphasized the action of the sea in producing the lagoons. We must add that in some places the reefs are progressing seawards on the outward margins by coral growth, whilst the area of the lagoons is increasing.

Small reefs occur irregularly in all the lagoons. In some places they represent portions of the original limestone mass; in others, as for example near the Easter Passage and at the N.E. end of the Pelsart lagoon, they have grown up from the floor of the lagoon.

Thus in the formation of the lagoons at the Abrolhos Islands the greatest factor has been that of erosion and solution. Coral growth has modified this action in places, and the heaping of coral blocks by waves and currents must be also taken into consideration. Subsidence has played practically no part in lagoon formation.

As to the future, the East and West Wallaby Islands and their adjoining fragments will be probably still further reduced. Rat Island in a similar manner will be further eroded, and the Easter Group become still more like a typical atoll. The depth of the Pelsart lagoon at the extreme southern end will probably decrease owing to deposition of material washed over the encircling reef.

APPENDIX.

In the concluding section immediately preceding this, a short summary of the observations on the coral formations of the Abrolhos Islands has been given. To this we may add a short summary of other data.

1. The Percy Sladen Trust Expeditions to the Abrolhos have been arranged for the purpose of obtaining information regarding the formation of the islands, the conditions permitting of coral-reef formations in this southern

latitude (the Abrolhos are probably the most southern coral islands in the world), and the fauna of this region of the southern Indian Ocean.

2. There is evidence that the temperature of the sea at the Abrolhos is usually some degrees higher than at the adjacent coast, and that as a result the temperature during the winter months rarely falls below 20° C.

3. In consequence of this hydrographical condition, the temperature of the water at the Abrolhos only very exceptionally falls below a point that is detrimental to the active growth of reef-building corals.

4. The difference in temperature between the coastal waters and those 50 miles out, is due to a tropical current from the North and North-East, which passes down the coast but is deflected away from it, leaving a strip of colder water against the land.

5. Any phenomenal preponderance of tropical species in the marine fauna of the Abrolhos region of the Indian Ocean is due to this tropical current. It remains to be seen, when the collections are worked up, to what extent the marine fauna is a mixture of Tropical and Southern types*.

6. A great blank in our knowledge of the distribution of marine organisms in the southern Indian Ocean will be filled up by the study of these collections from the Abrolhos region in conjunction with those to be obtained from an expedition to the north-western coast of Australia, which is to follow as part of this investigation.

The collections so far examined give every indication of this, as for example the record of a new Enteropneust, and many species of other groups for the first time on the West Australian coast.

EXPLANATION OF THE PLATES.

PLATE 10.

[Fig. 1.] Face of Limestone cliff, Turtle Bay, East Wallaby Island.

PLATE 11.

[Fig. 2.] Lesser Noddy, on nest in Mangrove Swamp.

PLATE 12.

[Fig. 3.] Noddy Terns nesting on Rat Island.

PLATE 13.

Fig. 4. North-eastern coast of East Wallaby Island.
Fig. 5. Limestone cliffs, Turtle Bay, East Wallaby Island.

PLATE 14.

Fig. 6. Undercut Limestone, North Island.
Fig. 7. Limestone "Pinnacle" on reef-flat, West Wallaby Island.

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* The fishes, at least, appear to be chiefly Southern forms.

Restorations of the Head of *Osteolepis*. By EDWIN S. GOODRICH, F.R.S., Zool. Sec. L.S., Fellow of Merton College, Oxford.

(With 6 Text-figures.)

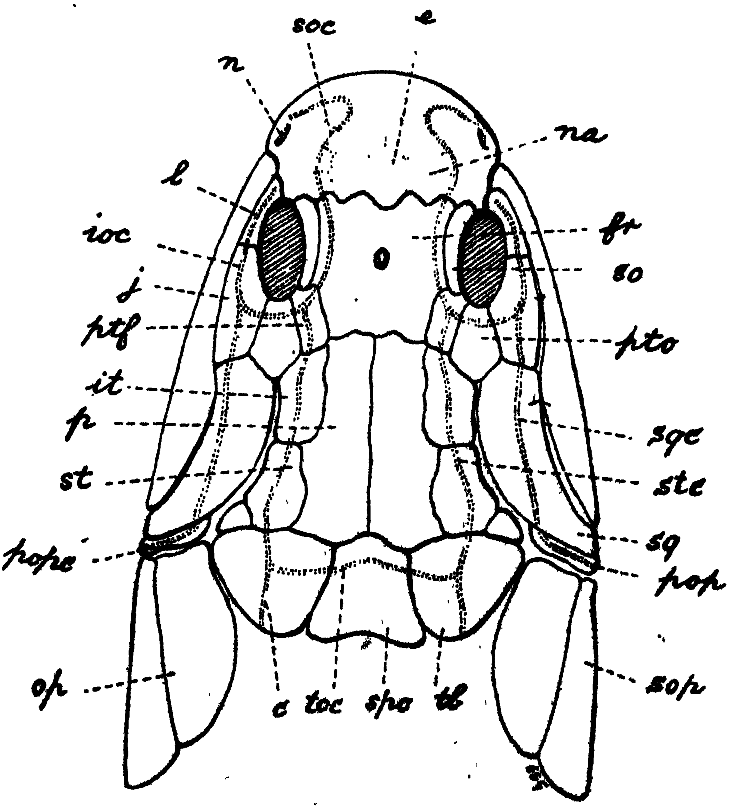
[Read 17th January, 1918.]

THE genus *Osteolepis* is one of the commonest and best-known of the early Devonian Teleostomes. Nevertheless the exact disposition and homology of the superficial bones of the head are still but imperfectly understood. Two recently published restorations of the head, one by Gregory (6) and the other by Watson and Day (14), differ so remarkably from each other that it seemed advisable to reinvestigate the subject; for the Osteolepidæ are a very interesting and important group. In many respects, as for instance in the form of the paired fins and in the cosmoid structure of the scales, they approach the Devonian Dipnoi such as *Dipterus* (Goodrich, 4, 5); while, on the other hand, the skull shows undoubted affinity with the early Amphibia (Stegocephali). Huxley, I think unfortunately, in his valuable work on the fishes of the Devonian epoch (7), included *Osteolepis* and its fossil relatives together with *Polypterus* in the one group Crossopterygii. *Polypterus*, however, as I have endeavoured to show elsewhere (5), really differs fundamentally in its structure from the Osteolepids, and is almost certainly an aberrant Actinopterygian preserving some primitive characters. But, however this may be, there can be little doubt that the Osteolepidæ have departed less from the structure of the common ancestor of the Teleostomi and Tetrapoda than any other known fish. A thorough understanding of the structure of the skull of *Osteolepis* is, therefore, of the greatest importance for the elucidation of the homologies of the bones in the higher Vertebrates.

The most complete restorations of the skull of *Osteolepis* yet published are those given by Pander in his well-known monograph (10). But, beautiful as are his figures and excellent his reconstructions, they can by no means be trusted in every detail. Since then, Traquair has contributed a very good restoration of the whole fish (13), without detailed figures of the head; and Smith Woodward in his text-book (15) has given a figure of the roof of the skull, which is in all essentials correct. As already mentioned above, in his interesting discussion of the origin of the Tetrapoda (6) W. K. Gregory has figured restorations of *Osteolepis microlepidotus*, admittedly based on Pander's work; while D. M. S. Watson and H. Day, in their valuable paper on "Palæozoic Fishes" (14), restore *Osteolepis macrolepidotus*. Three sets of these figures from Pander, Gregory, and Watson & Day are here reproduced for comparison (figs. 2, 3, 4, & 5).

For my own restorations (figs. 1 A & B) I have not only had the benefit of the work of my predecessors, but have been able to study a large number of excellent specimens in various collections. I have to thank the authorities of the Museum of Practical Geology, Jermyn Street, for affording me every facility for the study of the fine series in their keeping, also Prof. Sollas for the loan of specimens in the Geological Department of the Oxford University Museum; but more especially Dr. A. Smith Woodward for his unfailing kindness and helpfulness during my frequent visits to the British Museum of Natural History.

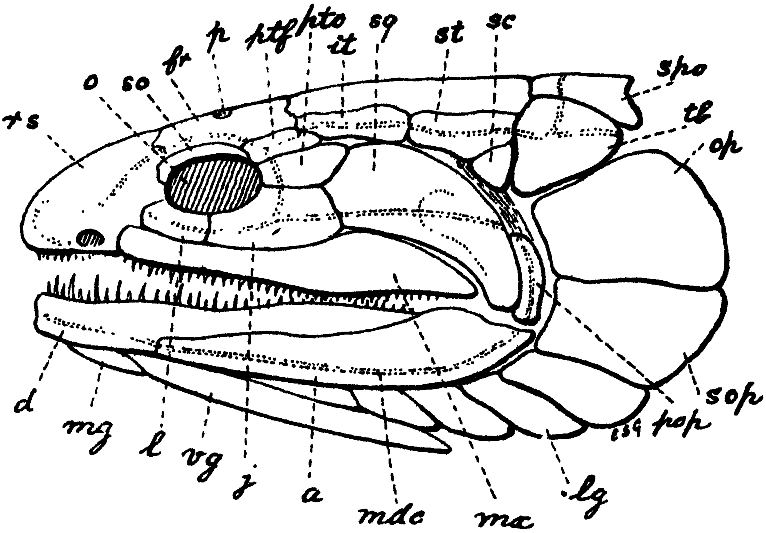
Fig. 1 A.



Restoration of the head of *Osteolepis macrolepidotus*, Ag.
Dorsal view, enlarged.
(For lettering see fig. 1 B.)

As for the general disposition of the skull-plates covered with cosmine the figures speak for themselves, and only certain points of doubt or disagreement need be discussed in detail. First of all it may be mentioned that, although my restorations apply more particularly to *O. macrolepidotus*, yet I find no important difference between that species and *O. microlepidotus*. The most careful scrutiny has convinced me that the supposed transverse series of small plates behind the parietals figured in *O. microlepidotus* by Pander, and accepted by Gregory, are not separate elements. They are parts of the supratemporals and parietals, and the often incomplete lines which were supposed to be sutures marking them off from these bones are merely superficial grooves involving only the cosmine layer, and possibly indicating the presence of rows of small pit-organs or some other sensory structures. I can find no evidence of the existence of such a transverse series in any other Osteolepid; and an examination of the under surface

FIG. 1 B.



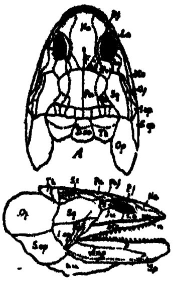
Restoration of the head of *Osteolepis macrolepidotus*, Ag.

Left side view.

a, angular; *c*, main lateral-line canal; *d*, dentary; *e*, ethmoid included in rostral shield; *fr*, frontals fused in middle line and enclosing the pineal opening; *ioc*, infra-orbital canal; *it*, intertemporal; *j*, jugal; *l*, lacrymal; *lg*, lateral gular; *mdc*, mandibular canal; *mg*, median gular; *mx*, maxilla; *n*, nostril; *na*, nasal included in rostral shield; *o*, orbit; *op*, opercular; *p*, pineal opening; *pop*, preopercular; *popc*, preopercular canal; *ptf*, postfrontal; *pto*, postorbital; *rs*, rostral shield; *sc*, scale-like plate overhanging hyomandibular; *so*, supraorbital; *soc*, supraorbital canal; *sop*, subopercular; *spo*, dermal supraoccipital or postparietal; *sq*, squamosal; *sqc*, squamosal canal; *st*, supratemporal or pterotic; *stc*, supratemporal canal; *tb*, tabulare; *toc*, transverse occipital canal; *vg*, ventral paired gular.

shows in this region the bone stretching uninterruptedly from three centres of ossification on each side, and three only : the parietal, the intertemporal, and the supratemporal. Grooves similar to those just mentioned are found on the frontals, diverging from the hinder border (as figured by Pander, see fig. 5), on the squamosal, and on some of the trunk scales running between the lateral-line scales and the mid-dorsal line. The diverging lines on the frontals do not mark off the postfrontals as suggested by Gregory; these bones are distinct but small, harbour the lateral-line canal, and seem just to reach the edge of the orbit. A distinct intertemporal is present. A suture separates the two parietals; but the frontals are fused superficially, although the suture can be distinguished on the inner surface. In one specimen a small plate and a minute nodule, possibly transparent in the living, were situated in the pineal foramen. Jaekel figures several such plates in *Diplopterus* (8). In front of the frontals the snout is covered by a shield formed of small plates the outlines of which can still be distinguished

Fig. 2.



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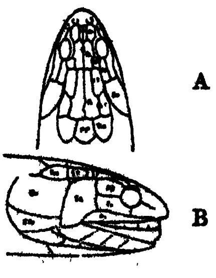

Fig. 2. Restoration of the dorsal, A, and right side, B, of the head of *Osteolepis microlepidotus*, Ag., from Gregory (6).

Fig. 3. Restoration of the dorsal, A, and right side, B, of the head of *Osteolepis macrolepidotus*, Ag., from Watson & Day (14).

Lettering for figs. 2 & 3:—

D, dentary; *D.So.*, dermal supraoccipital; *F* & *Fr*, frontals; *Gu*, gular; *I.op.*, interopercular; *It*, intertemporal; *Ju*, jugal; *La*, lacrymal; *Mx*, maxilla; *n*, nostril; *NA*, nasal; *OP*, opercular; *PA*, parietal; *Pf*, prefrontal; *P.O.* & *Po.O.*, postorbital; *Po.Fr.* & *Po.f.*, postfrontal; *P.P.*, postparietal; *Q.j.*, quadratojugal; *Sp*, splenial; *Sq*, squamosal; *S.OP.*, subopercular; *S.T*, supratemporal; *TAB* & *Tb*, tabulare.

to some extent on the inner surface. Unlike Watson and Day, I find here a fairly large median ethmoid between the nasals. Almost at the extreme lateral edge of the rounded rostrum can usually be seen an external nostril, which in some specimens is certainly surrounded by bone; while the position of the lower or posterior nostril is perhaps indicated by a notch on the recurved ventral border of the shield. At the hinder corner of the skull, between the squamosal, tabulare and supratemporal, is a small triangular plate, figured by Pander and Gregory but not by Watson and Day. This scale-like plate seems to have been attached to the supratemporal and possibly overhung a spiracular opening. Below it passed the head of the large curved hyomandibular (traces of which can often be seen) to articulate with the supratemporal.

The lateral aspect of the head is by far the most difficult to interpret since the bones are here almost always much crushed and displaced, especially near the articulation of the jaws. Nevertheless, there can be no doubt of the existence of a large curved squamosal covering the whole of the cheek behind the postorbital and jugal. It has been well figured by Watson and Day, but Pander seems to have considered that it consisted of three plates, being partly misled by the curved superficial groove shown in figure 1 B. The squamosal reaches down to the articulation of the jaws, covering the quadrate region. Just behind its hinder edge, and overlying the end of the hyomandibular, is a small plate, the preopercular. This element is not figured by Watson and Day, but is possibly the one drawn by Pander and designated quadratojugal by Gregory. If so, its true position has not been correctly determined by these authors. For a long time I doubted the existence of this separate element which is almost always considerably displaced; but after very careful examination of the most favourable material was finally convinced of its presence. The conspicuous large opercular bones pass ventrally into a series of lateral gular or bramchiostegal plates, which end in a pointed anterior element wedged in between the ventral gular and the lower jaw. Pander's restoration of the lower jaw appears to me much more correct than that of Watson and Day. No trace could be found of the series of infradentaries figured by the latter authors. The dentary and angular are obvious; an 'opercular' or prearticular plate seems to have covered part of the inner

FIG. 4.

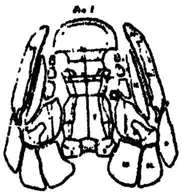

FIG. 5.

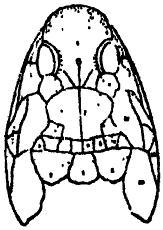

Fig. 4. Diagram of the bones of the skull of *Osteolepis macrolepidotus*, from Pander.
Fig. 5. Restoration of head of *Osteolepis microlepidotus*, from Pander.

surface, while further forward there are indications of a splenial showing on the lower outer surface. Of the existence of this element, however, I could not make certain.

Special attention was devoted to the course of the lateral-line system. It is not included in the figures of Watson and Day; but Pander studied it with considerable success. Recently it has again been figured by Collinge (3) without, however, adding much to Pander's results. These authors seem to have indicated in their restorations the distribution of the lateral-line pores rather than of the canal itself. The distribution of the two is by no means always the same, since the pores often stray far from the canal with which they are connected by delicate branches, and may be dotted about somewhat irregularly. The double broken line in my figures indicates the course of the canals only, as they are often beautifully revealed in the fossils.

The main lateral-line canal passing from the body scales enters the hinder region of the tabulare (often called supratemporal), runs forward through the supratemporal (pterotic), intertemporal, and postfrontal. About the middle of the tabulare it gives off a transverse occipital branch which joins its fellow from the opposite side in the median dermal supraoccipital (postparietal). That portion of the canal which lies between the origin of the transverse occipital and the origin of the infraorbital branch may be called the temporal canal. It is generally considered to belong to the infraorbital. In the postfrontal the canal branches into an upper supraorbital and a lower infraorbital canal. The former proceeds along the margin of the frontal to the rostral shield, where it describes an elegant curve and appears to end close to the nostril. I could find no anterior commissure; if such exists it must be on the ventral surface of the snout. The hitherto unrecognized junction of the supraorbital canal in the postfrontal bone with the infraorbital canal which runs up through the postorbital from the jugal I have been able to trace quite clearly. In the jugal a horizontal branch is given off from the infraorbital canal; it passes backwards across the squamosal, and apparently joins the preopercular canal which enters the angular; and proceeds forwards to the front end of the dentary.

These lateral-line canals are of special importance when comparing the skull of fishes with that of the primitive Tetrapoda. Pollard (11), Baur (2), Allis (1), and especially Moodie (9), have already made use of the canals in *Amia* and *Polypterus* in comparison with the Stegocephali, where the course of the lateral line is often marked by grooves. But these modern fish are specialized in many respects, and the pattern of *Osteolepis* agrees more closely with the Stegocephalian (see Moodie's figures, 9). However, it is not proposed to enter into a detailed discussion of the comparison in this paper, but it may be pointed out that the horizontal squamosal canal mentioned above is characteristic also of the Stegocephali. It is possibly represented by the 'hyomandibular canal' of Selachians. A further study of this region in the Stegocephali might enable us to determine the homology of the lateral bones of the skull, especially of the quadratojugal, which is still very obscure. Judging from modern forms, the preopercular canal must have been supplied by a postspiracular branch of the hyomandibular nerve; we should not, therefore, expect to find it and the bone containing it in the skull of an Amphibian. Although a canal is known to have been present in the lower jaw of some Stegocephalians, its connexion with the more dorsal canals does not seem to have been made out. The settlement of this important point might help us to determine whether the preopercular is really represented in the Amphibian skull or not.

In conclusion attention may be drawn to the remarkable uniformity in the structure of the skull among the Osteolepidæ. *Thursius*, *Diplopterus*, and even *Megalichthys* seem to differ in no important respect from *Osteolepis* in the number and disposition of the bones on the head. The Rhizodontidæ also closely resemble the Osteolepids; and, except for the presence of infradentaries and for the subdivision of the squamosal, the restorations of *Rhizodopsis* made by Traquair (12), that most accurate of observers, would serve almost equally well for *Osteolepis*, as may easily be seen by comparing his figures with mine.

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A Post-Puerulus Stage of *Jasus lalandii* (Milne Edw.), Ortmann. By J. D. F. Gilchrist, M.A., D.Sc., Ph.D., F.L.S., Professor of Zoology in the University of Cape Town.

(Plates 15 & 16, and 13 Text-figures.)

[Read 3rd April, 1919.]

Since the description of the early larval stages of the Cape Crawfish in the Journal of the Linnean Society (4, 5) further information has been obtained and may be put on record. It is now possible also to compare the results with what has been done in the case of the New Zealand Crawfish, which, after careful examination by Miers, Haswell, Parker, McCoy, and Ortmann, is now accepted as identical with the Cape species. Some of the early stages of this have been noted by Thomson (8), Calman (3), Archey (1), while Gruvel (6, 7) and Bouvier (2) have directed attention to young stages found at the Island of St. Paul, thus affording material for comparison and the further building up of the life-history of this widely distributed crustacean.

The object of this note is the filling in of another gap in the life-history, by a description of the stage immediately succeeding the puerulus stage, and representing the transition to the adult form, but differing from it in some respects. This was rendered possible by the procuring of living specimens in the puerulus stage, and rearing them to the next stage. This afforded also an opportunity of observing the habits of the puerulus, which may be first noted.

The specimens were procured by trawl in Table Bay on four occasions in the months of November and December in 5 to 14 fathoms of water, and were transferred to the Marine Laboratory at St. James near Cape Town. They proved to be very active animals. When placed in the tank, they immediately darted to the bottom by a strong flexure of the tail, and hid themselves below the weed and stones placed there. When driven out of these places they quickly sought refuge elsewhere, sometimes on the under surface of some weed floating at the surface of the water. Contrary to what was expected, they were never observed to swim about by means of their abdominal appendages, which are specially well developed at this stage, as if for this purpose. They seem to be vegetarian in their habits, as they fed on the seawoed, but not on animal food placed beside them in the tank. The flesh of fish, crabs, and molluscs was offered them, but they paid little or no attention to it.

The most noticeable change observed was in the colour. When first procured they were very transparent, with the exception of a few bright spots of a reddish colour on the under side of the body. After about three days in the tank, some of them were observed to be assuming a darker shade, of a brownish colour. This appeared first on the antennæ, occurring at intervals along their length as in the adult. Pigment then appeared on the large ocular spines behind the base of the eyestalk, and finally on the abdomen, legs, and thorax. On the thorax it appeared first at the spots where the new spines of the next stage are forming, giving the appearance of more spines than are really present in this puerulus stage (Pl. 16). This was very apparent when the first shell was cast, this being seen to have only the few spines already described, while the spines of the new cuticle are much more numerous. The late stage of the puerulus has the external appearance, therefore, of the post-puerulus stage, and this, as we shall see, has given rise to some confusion between the two stages.

The colour of the animal at this late puerulus and the beginning of the post-puerulus stage is of course identical, and was as follows in the living state:—The flagella of the antennæ had a series of dark rings at intervals, and, between these, were yellowish white in colour, which was also the colour of the second and third segments of the antennæ. The antennules were of a dark colour on the segments, yellowish between, and their extremities were bright red. The large frontal spines were of a bright pinkish red colour, the other spines greyish brown. This last colour was also found, usually in the form of a patch or stripe, on the segments of the walking-legs, the joints between them being a light yellow. The whole carapace, excepting the spines, was also of a light yellow colour. The abdominal segments had patterns of slaty purplish-brown colour, which was again seen on some of the spines of the telson.

The bright pink spots of the underside of the body, characteristic both of the phyllosoma and the puerulus, begin to grow fainter at the time of the assumption of the general coloration of the body above described, and have disappeared completely by its completion.

Both the late puerulus and post-puerulus stages have been found in the sea in tow-nets, and these show a more marked and brilliant coloration, the red pigment of the antennules and rostral spines appearing also on the walking-legs. The general coloration is shown in Plate 15, drawn by Mr. G. Birbel from a specimen just captured.

In about a week after the puerulus was put into the tank the cuticle was shed. Only one individual, however, survived this process, and this one died soon afterwards. Most of them were able to free themselves completely from the abdominal region and the thorax, and, to a large extent, from the appendages, but the gill regions seemed a source of trouble in getting rid of the old cuticle. This partial ecdysis, however, had the advantage of rendering it possible to compare any particular part of an individual puerulus with the part which succeeded it in the next stage. That this next stage was not a repetition of the preceding, but involved a more or less marked metamorphosis, will be seen from the following description of the changes involved.

The recognised characters which distinguish the larval puerulus from the adult are (1) the large size of the pleopods, and particularly the presence of special coupling hooks at the end of the *appendix interna*, which join the pleopods of opposite sides of the body together in pairs, (2) carapace and telson with few spines, the former being somewhat square in transverse section, and having distinct lateral ridges, (3) presence of exopodites on the thoracic appendages, (4) third maxillipedes separated at their bases, (5) absence of cervical groove ; and to these I may add others which seem of importance, namely (6) character of the mandible, and (7) a fan-like group of setæ on the antennules, which may for convenience be referred to as the "antennular screen."

The changes which take place in these features in the transition to the next stage are as follows :—

(1) *The Pleopods.*

The metamorphosis of the pleopods is shown in figs. 1 and 2, which are camera lucida drawings of the last pleopod of the right side, showing the cast cuticle, and the organ which has taken its place, both from the same animal. It will be observed that the exopodite has become smaller, but the chief reduction in size is in the endopodite and the *appendix interna*, both of which undergo a reduction to about three-fifths of their former size. A marked change is also observed in the plumose setæ, which cover both sections of the limbs in the first stage, but are only found in the exopodite in the next, the endopodite now being entirely devoid of them. The single long plumose seta, characteristic of the *appendix interna*, has also disappeared, but the most marked change is in the complete disappearance of the coupling hooks (fig. 2, *ch.*). Examination of later stages shows that apparently both in males and females the endopodite is similar, though in later stages the endopodite of the female is larger and setose, while in the male it disappears altogether.

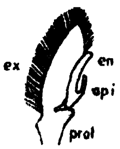


Fig. 1.—Last pleopod of post-puerulus.

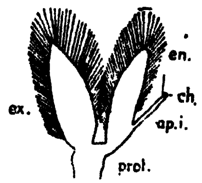


Fig. 2.—Last pleopod of puerulus.

ap.i., appendix interna; *c.h.*, coupling hooks; *en.*, endopodite; *ex.*, exopodite; *prot.*, protopodite.

(2) *Carapace and Telson.*

The carapace, with special reference to the arrangement of spines, has been described by Bouvier (2) in 1912, and Archey (1) in 1915. Bouvier's specimens were described by Gruvel (6, 7) as the young of *Jasus lalandii*, from three examples procured from the Island of St. Paul. Bouvier agrees that the puerulus is to be referred to this species, both from the fact that this is the only palinurid found on the island, and from his examination of the specimens.

The arrangement of the spines of the carapace he describes as follows: "Outre les deux paires d'épines frontales caractéristiques des puerulus, la carapace présente une épine gastrique et, de chaque côté, deux épines branchiales antérieures, l'une à l'extrémité même de l'arête dorso-latérale, l'autre située un peu plus en arrière et au voisinage de la région gastrique. On observe à l'état de rudiments une paire d'épines gastriques postérieures, deux paires successives d'épines cardiaques, et un rangée d'épines marginales postérieures."

Archey's specimens were from Stewart Island, New Zealand, and he describes the spinulation of the carapace as follows:—"Supra-orbitals large, projecting upwards and outwards, with a very small spine immediately at their bases; post-orbital smaller than supra-orbital and each with a still smaller spine behind." Further details are indicated in his figure, which shows two small spines at the base of the median gastric, and three pairs of cardiac spines, that is, more spines than in Bouvier's specimen. He states that the spines though few are distinct, while Bouvier found that the posterior gastrics and the cardiac, as well as the marginal spines, were rudimentary and were much in the form of "saillies obtuses très peu visibles."

In the Cape specimen (5) no spines were found alongside of the median gastric, no pair of posterior gastrics, and only one pair of cardiacs, while the row of marginal spines found both by Bouvier and Archey were not seen.

All these accounts therefore, of the number and arrangement of the spines, differ from each other, and it would appear either that there may be a variation in the species in the widely separated localities from which the specimens were procured, or that, if a larger number of specimens had been available for examination, individuals would have been found to vary considerably. The question as to whether or not the puerulus, as well as the succeeding stages, are characterised by the possession of a definite number and arrangement of spines is an important one in any attempt to follow out the life-history of the animal in detail, and, with a view to throw some light on this point and the apparent discrepancy in the descriptions, all the Cape pueruli procured (about 30) were re-examined. It was found that, while all of them had the thirteen spines which I originally described (5), a good many showed, on closer examination, a varying number of small additional spines, and a few, many more than in any of the three accounts. The meaning of this became apparent when the specimens, which had been reared to the post-puerulus stage, were examined, and it was possible to compare the cast cuticle of the puerulus stage with the new cuticle of the stage following. The cast cuticle, when examined by a lens, showed only the fifteen spines, as originally described, while the new cuticle showed many more. These had not of course appeared suddenly, and the apparent presence of a varying number of additional spines, more or less distinct, in most of the pueruli, is due to the presence of spines arising under the old cuticle, but not affecting it. To make quite certain that there were no additional spines even in the form of obtuse projections of the cuticle, it was examined in all positions by a lens. The cuticle of the post-puerulus stage was then removed from the body and examined microscopically along with the cast cuticle. Figs. 3 and 4 are camera lucida drawings of the two, showing the general arrangement and number of the spines. It will be seen that three of the spines in the puerulus are merely slight elevations of the cuticle, namely the median gastric and the single pair of cardiacs, all the others being well developed and with sharp points. The cardiacs alone had a few setæ. The cuticle of the post-puerulus, on the other hand, had all the prominent spines

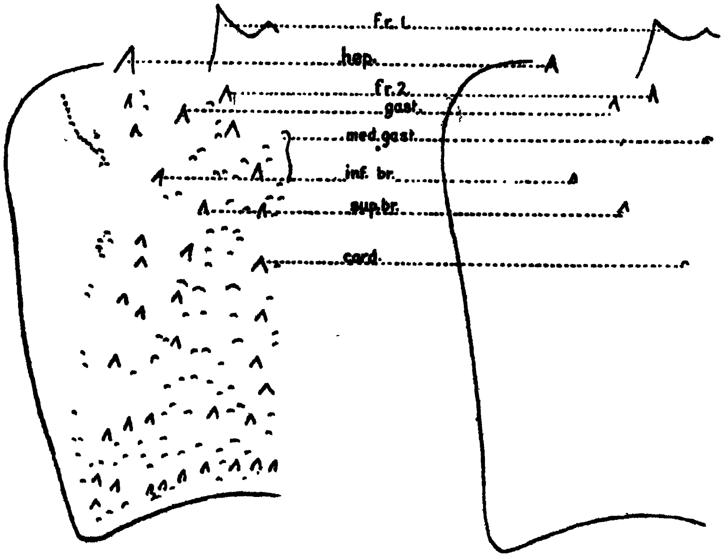


FIG. 3.—Spines of carapace of post-puerulus. Spines of carapace of puerulus.
card., cardiac; *fr.* 1, frontal; *fr.* 2, small spine behind it; *gast.*, gastric or post-orbital; *hep.*, hepatic; *inf. br.*, first inferior branchial; *med. gast.*, median gastric; *sup. br.*, first superior branchial.

of the adult, and most of the others were represented by rounded prominences provided with hairs. In a late puerulus with all the spines developed, it may be observed by using a lens (though with some difficulty) that these spines lie under the smooth surface of the cuticle of the puerulus. That this is really the case may, however, be placed beyond doubt if sections are made across the animal in a late puerulus stage. Fig. 5 shows such a section across of the posterior marginal spines, and it will be seen that they do not affect the puerulus cuticle. It may be reasonably concluded, therefore, that the puerulus stage, so far as the evidence goes, is characterised by a definite number of spines on the carapace, and it may be provisionally assumed that other young stages may also be determined in this way.

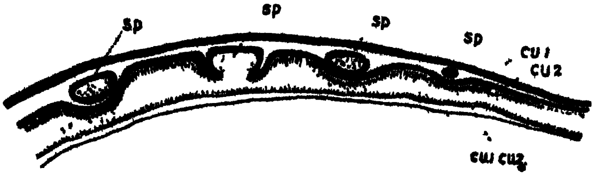


FIG 5.—Transverse section of posterior margin of carapace of a late puerulus. *cu.* 1, cuticle of puerulus; *cu.* 2, cuticle of post-puerulus; *sp.*, spines of post-puerulus.

What has been said of the spines of the carapace applies also to those of the telson. The telson of a post-puerulus stage and its cast cuticle of the puerulus stage were compared microscopically, and a very distinct advance noted (figs. 6 & 7). In the puerulus there is a pair of strong spines in the centre of the anterior end; between these and the first marginal spine are two more spines, there being a third, of small dimensions, at the base of the first marginal spine and forming part of it. The marginal spines are five in number, the last being indistinct. Besides these there were no others. In the post-puerulus telson, however, there is a conspicuous double row of ten spines running along the centre, and, on each side, three rows of less regular

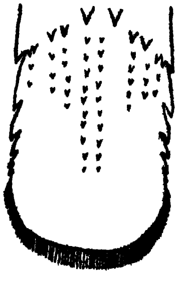


FIG. 6.—Telson of post-puerulus.

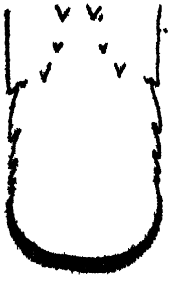


FIG. 7.—Cast cuticle of telson of puerulus.

arrangement and fewer spines. There are still, as in the puerulus, two spines between the large anterior median spines and the first marginal. They are, however, closer together and there is an additional small spine at the base of the first marginal. These marginal spines are now six in number, this being the number in the adult, where, however, there are four accessory spines to the first marginal, and the other marginals have accessory spines. In some of the larger phyllosomas, believed to be of *Jasus*, there were two median anterior spines and three marginal spines on each side of the telson. These latter, however, were not free, but under the cuticle.

Before leaving the carapace it may be mentioned that there is in the post-puerulus no trace of the lateral ridges of the puerulus stage, the carapace being rounded as in the adult.

(3) *Exopodites of walking-legs.*

One of the legs was compared with its cast cuticle and no trace of the exopodite, which is easily seen in the cast cuticle, was found in the new limb. There was, however, a slight bulging of the cuticle, apparently marking the place of the exopodite.

(4) *Third maxillipedes.*

No marked difference was observed in the two stages with regard to the relative position of these appendages, being widely separated at the bases in both. This is readily observed and may be a useful character to separate this post-puerulus from succeeding stages, for in a specimen only 27 mm. in length they are close together. The exopodite in the post-puerulus was, however, decidedly longer, reaching to the meropodite as in the adult. The additional length was made up of a segmented flagellum. The relative length of the non-flagellar parts is the same from the puerulus to the adult (figs. 8 & 9).

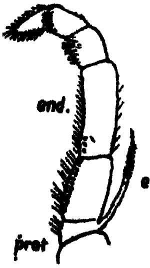


FIG. 8.—Third maxillipede of post-puerulus.

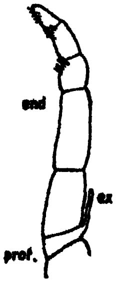


FIG 9.—Third maxillipede of puerulus.

en, endopodite; *ex.*, exopodite; *prot.*, protopodite.

(5) *Cervical groove.*

The absence of a cervical groove is said to be a distinctive feature of the puerulus. This was found in the post-puerulus stage, but not so well marked in the dorsal region of the body as in the lateral regions, especially in front of the two large anterior branchial spines. On microscopic examination it was seen that this part was well defined by a line of low elevations of the cuticle (fig. 3) which become the row of spines bounding the hepatic region in the adult.

(6) *Mandibles.*

An interesting difference, and perhaps one of the most important, between the puerulus and post-puerulus is found in the changes which have taken place in the mandibles. These seem not only to distinguish the two stages from each other, but also both from the adult condition. Thus, in the puerulus stage, the mandibles are provided with a thick cuticle, which shows no differentiation except three low prominences on the cutting surface.

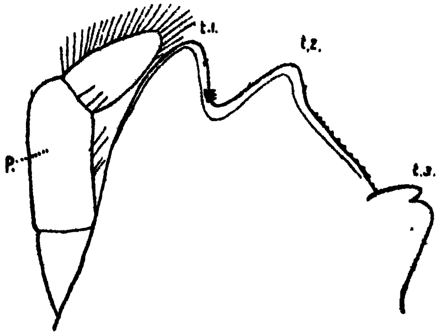


Fig. 10.—Mandible of post-puerulus.

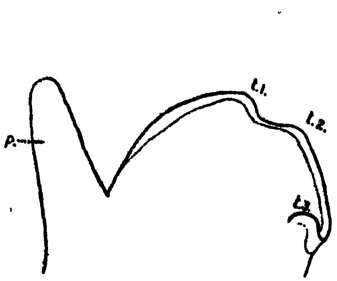


Fig. 11.—Mandible of puerulus.

p., mandibular palp; *t.* 1, *t.* 2, *t.* 3, teeth of mandible.

The first and second of these, counting from the side next the mandibular palp, are usually close together, though, in some cases, all three are about equidistant. The third being situated somewhat internal to the other two, though still forming part of the cutting-edge, I formerly suggested (4) might prove to become the molar or grinding part of the adult mandible. An examination of the post-puerulus does not, however, entirely confirm this.

The changes which have taken place are illustrated by figs. 10 and 11, which are camera lucida drawings of the shed cuticle of a puerulus and the mandible of the post-puerulus stage, which takes its place, both from the same specimen. The mandibular palp (*p.*) is now fully formed and is provided with three segments and setæ. The beginning of the mandibular spine is also indicated but only by a clear line in the cuticle, which will form the hinge of the mandible. The three prominences or teeth of the mandible are more marked, and a cutting-edge on which there is a series of small denticles of irregular shape, has appeared between the second and third. A few of these appear also on the first and second tooth in some specimens, not in all, and, at their base, a large one was in all cases found, ending in three sharp points. These denticles are readily distinguished from the rest of the thickened cuticle, on which they lie, as they are of a dark brown colour. Doubtless their appearance is associated with the change in the feeding habits of the animal. They disappear in the subsequent stages, in which the mandible has become calcified.

The change in the third tooth is marked. From a mere undulation of the cuticle in the puerulus it has now become prominent and conical, with a cleft apex, and is situated behind the cutting denticulate outer margin of the mandible. The part which it takes in the formation of the adult mandible is now apparent, for in the latter the main part of the molar surface is formed by a cleft or V-shaped prominence, which is apparently the transformed third tooth. The inner limb or ridge of the prominence forms the thick posterior margin of the molar surface. The whole of the molar surface is, however, not formed from the third tooth; for, behind the second tooth, there is a ridge running backwards, which fades off into a rounded prominence, thus forming the rest of the molar surface.

The second tooth therefore undergoes a transformation similar to that which occurs in the third, for it becomes a V-shaped ridge, one limb of which forms the outer cutting-edge of the mandible and the other the molar ridge just mentioned. The bifurcate characters of the second and third teeth are better seen in the early calcified stages than in the adult where, however, they can readily be made out. Thus in a small crawfish 27 mm. in length, in which the mandibles only are calcified, and in a later stage 32 mm. in length, in which both mandibles and cuticle of the body generally are calcified, these two V-shaped structures are readily distinguishable.

(7) *Antennular screen.*

Another marked change in the transition from the puerulus to the post-puerulus is the disappearance of a bundle of long feathered setæ, arranged as a fan-shaped structure, on the upper side of the distal end of the first segment of the antennule. It is not readily seen in a surface view, as it lies at right angles to the axis of the antennule, and it is obscured by the thick antennæ in a lateral view. If, however, the antennules are removed and viewed laterally, the setæ are very obvious. There are about half a dozen of them all inserted close together in a short transverse furrow, thus forming a sort of screen in front of the auditory pit, which lies at the other end of the same segment. The auditory pit is as yet widely open, and is protected by short feathered setæ round its margin, so that it seems not an unreasonable conjecture that this screen is for the further protection of the organ at this stage, the large antennæ forming effective protections at the sides. Its function may, however, be sensory, but, whatever it be, the structure would appear to be necessary only at this stage, as it is absent in the phyllosoma, and very much reduced in the post-puerulus. Fig. 13 shows the structure in the shed cuticle of the puerulus and fig. 12 its reduced condition in the antennule, from which it was cast off. The setæ have, in the second stage, become very much shorter, so that, whereas they could reach beyond the distal end of the second segment in the puerulus when bent forwards, they now could scarcely reach to the distal end of the first segment.

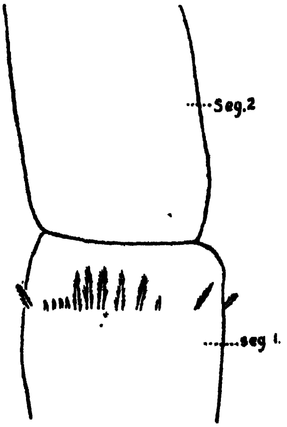


Fig. 12.—Reduced antennular screen in post-puerulus.

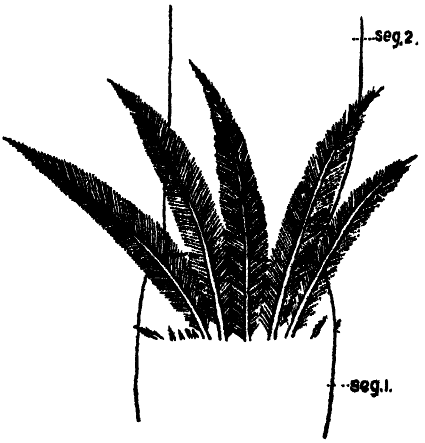


Fig. 13.—Antennular screen in puerulus.

seg. 1, first segment of antennule; *seg.* 2, second segment of antennule.

In older specimens the setæ become further reduced, though, even in the largest crawfish, they are found in this position. The furrow, however, in which they are lodged is well marked, though relatively shorter, being in the adult about a fifth of the diameter of the antennular segment. It is somewhat semilunar in shape, the concavity being directed forward. It has a number of pit-like depressions for the setæ, and these are often separated by marked prominences in the cuticle. In front of this semilunar furrow is a shallow depression in which the setæ lie. The persistence of this organ, in the adult in such a definite form, seems to suggest some function, which of course cannot be, in this case, the protection of the auditory cavity.

(8) *Colour.*

The colour of the post-puerulus stage has been described above. This, as pointed out, appears in the later puerulus stages, and is accompanied by the appearance of the new spines of the succeeding stage. To be quite accurate therefore, if we are to regard the increase of spines as a characteristic of the second stage, we must also consider the coloration to be so, the puerulus being strictly colourless, except for the bright spots on the under surface, found also in the phyllosoma.

Neither in the puerulus nor post-puerulus does the median rostral tooth meet the antennular segment as in the adult, a fact already noted in some specimens in the British Museum, from Stewart Island, New Zealand, and briefly described by Calman (3), who was the first to throw light on the real significance of the genus *Puerulus*. In a specimen with well calcified cuticle and 32 mm. in length it just touches it. In a larger specimen of about 40 mm. two slight projections of this segment were seen on each side of the tooth, but not clasping it, as in the adult.

The same is true of the relative length of the antennular and antennary peduncle, the former being markedly the shorter both in puerulus and post-puerulus, and even in much more advanced specimens, about 55 mm. in length, they are only about equal, though decidedly longer in the adult. This feature therefore cannot be regarded as characteristic of the puerulus only.

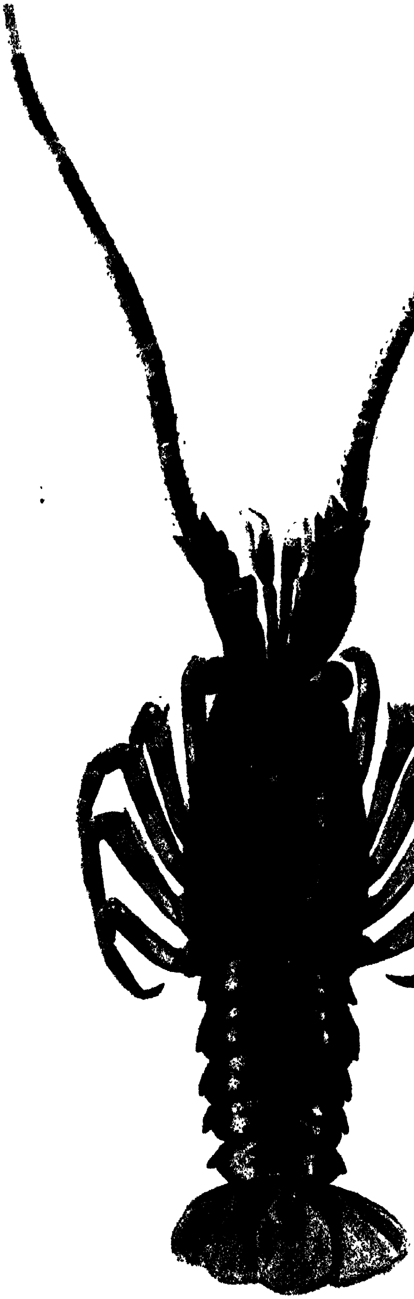
A comparison of the earlier stages, the naupliosoma and phyllosoma, of the *Jasus lalandii* of the Cape with that of New Zealand is of interest. That this first stage is also found in the New Zealand crawfish is now established. In the year 1906 Mr. G. M. Thomson (8) described a stage of *Jasus lalandii* which resembles the naupliosoma (4), but the antennules, not the antennæ, are described as bearing plumose setæ. A further discrepancy is the presence of five pairs of pereiopods, instead of three found in the Cape phyllosoma. Mr. Thomson kindly sent me a copy of his note, which is readily overlooked as it is included in a paper by Mr. Anderton on "Observations on New Zealand Fishes." I suggested a re-examination of the New Zealand larva, in view of what I had found in that of the Cape crawfish, and in the year 1916 Archey (1), without however any previous knowledge of Thomson's paper, redescribed and figured these early stages of the New Zealand crustacean, and concluded that the first larval form is identical with that which I described in 1913. There are, however, some slight discrepancies: thus, for instance, he figures free setæ on the endopodites of the first and second pereiopods. This may be accounted for by the fact that the cuticle of the naupliosoma is first shed in these parts, and some of the subcuticular setæ may have thus become free, this part of the limb representing, therefore, part of the phyllosoma limb.

I may add that though I have here spoken of a post-puerulus stage, this is only for convenience. All such "stages" are artificial, and strictly there are as many stages as there are ecdyses before the adult form is reached.

Much remains still to be done before a fairly complete account of the early stages of the Cape crawfish can be given. Thus, the transition from the phyllosoma to the puerulus is not known, and the embryonic development is untouched. The first will be a matter of a lucky haul of the nets, the second is now being carried out. The material consists of stages from the first formation of the blastoderm to the time of hatching. It has not yet been completely examined, but I may state in connection with the present paper, that the nauplius stage in the egg was found to occur forty-two days before the time of hatching and setting free of the first larva.

Summary.

1. Several pueruli of *Jasus lalandii* have been kept alive to succeeding or post-puerulus stage, which shows the following changes:—
    - *a.* The red spots on the underside of the body disappear, and the whole of the upper parts become coloured.
    - *b.* The spines of the carapace (of a definite number in the puerulus) become much more numerous.
    - *c.* The antennules lose the antennular screen of the puerulus.
    - *d.* The mandibles resemble those of the puerulus in having three teeth, but differently disposed, and a cutting-edge has appeared. Denticles appear between and on the first two teeth, as well as along the cutting edge. The palp has become three-segmented.
    - *e.* The exopodites of the pereiopods have disappeared.
    - *f.* The exopodites of the third maxillipedes are longer, by the addition of a flagellum.
    - *g.* The cervical groove is well marked at the sides of the body.
    - *h.* The pleopods have become smaller, especially the endopodite, which is now devoid of setæ; the coupling hooks and seta of the *appendix interna* have disappeared.
    - *i.* The telson has additional spines.
2. The post-puerulus differs from succeeding stages in the following respects:—
    - *a.* Cuticle uncalcified.
    - *b.* The incisor part of the mandible is provided with denticles on the margin of its thick cuticle.
    - *c.* The pleopods show no sexual differentiation.
    - *d.* The third maxillipedes are separated at their bases.
3. The occurrence of a nauplioosoma stage has been confirmed in the New Zealand *Jasus lalandii*, and the phyllosoma and puerulus are similar.



G. L. Birbel, del.

Grout, sc. & imp

JASUS LALANDII.

JASUS LALANDII.

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EXPLANATION OF THE PLATES.

PLATE 15.

Drawing showing natural colours of the post-puerulus stage.

PLATE 16.

Four pueruli, showing various stages in colouring. From a photograph of specimens kept alive for six days.

On the Linnean Species of Non-Marine Mollusca that are represented in the British Fauna, with Notes on the Specimens of these and other British forms in the Linnean Collection.

By A. S. KENNARD, F.G.S., and B. B. WOODWARD, F.L.S.

[Read 21st November, 1918.]

THANKS to the active researches of Mr. C. D. Sherborn, A.L.S., for the 'Index Animalium,' prosecuted for now some thirty years, of Mr. Iredale, Mr. Reynell and others, our knowledge of the work of the earlier writers has been so greatly increased, especially of late, that there now seems some chance of approximate finality being attainable in the matter of nomenclature on the basis of priority—at least in the case of the British post-Pliocene non-Marine Mollusca with which we are particularly concerned.

Accordingly we are attempting a more thorough revision of their synonymy than essayed by us in 1903 (Journ. of Conch. x. pp. 352–367) and 1914 (List of the British Non-Marine Mollusca, 8vo, pp. 12).

Naturally one of the first steps in this undertaking has been to re-investigate the Linnean types, which have not been scrutinized since Hanley wrote his account of the whole collection of shells (Ipsa Linnæi Conchylia, 1855), save for the incompleted investigation of Mr. J. W. Taylor and Mr. W. D. Roebuck in May, 1914, when they "examined and isolated all the British land and freshwater shells" (Taylor, Monograph, iii. p. 17).

Now it had occurred to us that Linné's contemporary and correspondent, the celebrated O. F. Müller, was likely to have known more about the great Swedish Naturalist's work than was usually credited, despite the fact that many of Linné's species do not find place in Müller's 'Vermium Historia'; and we accordingly proceeded to test the supposition. The first point of importance in this connection proved to be that Müller in a paper on Fungi (Efterretning . . . om Svampe i sær Rör-Svampens velsmagende Pilse. 4to. Kiöbenhavn, 1763) described the slugs that fed on them, identifying three with Linnean species and describing, though not naming, two others. To one of these last Linné in the twelfth edition of his 'Systema Naturæ,' gave the name of *Limax albus*, citing Müller's paper (a copy of which is in his library) as his authority. Müller, however, omits in his 'Vermium Historia' (ii. p. 4) to quote this although elsewhere in its pages he refers abundantly and solely to this edition.

We then sought further evidence in the letters from Müller to Linné in the Society's possession, and under the kindly guidance of Dr. B. D. Jackson discovered the following postscript to his letter of 21 Novembr. 1767 :—

> “Testacea Sveciæ, si Tibi supersint mecum communicare precor, quæ sequuntur mihi nondum obvia.
>
> Mya lutraria.
> —— margaritifera.
> Bulla hypnorum.
> Turbo perversus.
> —— muscorum.
> Helix albella.
> —— complanata.
> —— spirorbis.
> —— arbustorum.
> —— fragilis.
> —— limosa.
> Nerita littoralis.
> —— lacustris.”

Beneath the address on the outside of the letter when folded, and in the left-hand lower corner, was written : —

> “avec un paquet
> marqué C. de L.”

An identical memorandum also occurs in the same position on another letter dated 21 May, 1773.

Another of Müller’s letters, dated 4 Martii, 1768, begins :—

> “Litteris tuis etsi & verbis & re satisferi, mittendo Tibi Stirpes, testacea ac dissertationes quasdam Italicas, adjecta prece ut mihi de his sententiam Tuam quam primum diceses, jam tamen per trimestre & quod excurrit sollicitus & incertus maneo.”

Thus it is evident that Müller sent molluscan specimens to Linné, but his request for information and specimens in return to help him in his work met no response as he complains in his Verm. Hist. (Tom. ii. p. 161).

Our next discovery was that the numbers on the little packets containing shells in the Linnean collection that are alluded to by Hanley seemed indubitably to be in Müller’s handwriting. The list of these is as follows :—

“N. 14 minima cavend. reper.”	containing	2 *Carychium minimum*, Müll.
“N. 18 citrina p **** [indecipherable]	”	1 *Polita radiatula*, Alder, and 1 *Zonitoides nitidus* (Müll.).
“No. 27”	containing	1 *Polita cillaria* (Müll.) and 1 *P. Draparnaldi* (Beck).
“No. 40”	”	1 *Hygromia hispida* (Linn.) and 1 *Helicella* sp. ?
“No. 44”	”	1 *Pupilla muscorum* (Linn.) [edentulous variety].
“No. 52”	”	a number of miscellaneous species of *Clausilia*.
“No. 53”	”	10 *Ancylus fluviatilis*, Müll.

In the box with the contents of No. 27 was a label "*Helix cellaria*," and in with No. 53 one "*Patella lacustris*." Both these labels are in an unrecognized handwriting.

There are likewise in the collection, but without any original information, specimens of :—2 *Pyramidula ruderata* (Studer); 8 *Helicella virgata* (DaC.); 20 *Cochlicella acuta* (Müll.); 1 *Vallonia excentrica*, Sterki (labelled by some one "*Helix pulchella*"); 2 *Helicodonta obvoluta* (Müll.); 3 *Helix aspersa*, Müll., ticketed in the unknown handwriting "*Helix grisea*," and 10 others including one with the remains of a label in script apparently of the date of the collection "Helix [* *] 2" in two lines; 2 adult and 7 juvenile specimens of *Helix pisana*, Müll.; 2 Clausilia, ticketed "*bidentata*," Ström's name evidently being meant; 4 *Succinea pfeifferi*, Rossm.; 1 *Limnæa palustris* (Müll.); 3 *Segmentina nitida* (Müll.), which had been wrapped in a scrap of paper bearing German print on both sides; a packet, the paper of which bore Swedish print on one side and Latin on the other, containing 3 *Planorbis umbilicatus*, Müll. [=*Pl. planorbis*, Linn.], 1 *Pl. carinatus*, Müll., 1 *Pl. albus*, Müll., with a juvenile example of *Helicigona lapicida* (Linn.), these several species have been distributed in different glass-topped boxes, but careful record given of their former association; 4 *Valvata piscinalis* (Müll.); 20 examples of *Pomatias elegans* (Müll.); and finally a specimen of *Unio tumidus*, Retz., on a tablet with single valves of two other species, with the sole comment in pencil "3 species." It will be observed that with the exception of *Pyramidula ruderata*, *Helicella virgata*, *Clausilia bidentata*, *Succinea pfeifferi*, and *Unio tumidus* all are Müllerian species, for the *Vallonia* was evidently sent as *Helix pulchella*, Müll.

Putting the above facts together it seems clear that cotypes of some at all events of Müller's species are included in the Linnean collection, and that the recognition of their presence explains some of the doubtful points that have attended the attempts to identify certain of Linné's species.

A Botanist first and last, the great Naturalist does not appear to have attached much importance to his collection of shells, nor to have preserved those obtained for and described in the 'Fauna Svecica.' Although these last may perhaps have suffered in the tribulations the collections underwent even in Linné's time, as recorded by Dr. B. D. Jackson (Proc. Linn. Soc., Sess. 125, suppt., pp. 1 & 2).

In passing under review the various species with which we are at present concerned it will be convenient to take them in the order of classification and under the nomenclature most generally accepted to-day, as follows, an * being prefixed to those which were recorded by Linné as present in his collection (*cf.* list by Dr. B. D. Jackson, Proc. Linn. Soc., Sess. 125, suppt. pp. 38–43), whilst the number of specimens is added in ( ) after the name:—

LIMAX MAXIMUS, &
—— FLAVUS.
No doubt attaches to the identification of these two species which are established by the references given to Lister's figures.

AGRIOLIMAX (LIMAX, L.) AGRESTIS.
Linné's reference to Lister, who remarks on its peculiar white mucus, suffices to show the species intended.

ARION (LIMAX, L.) ATER.
As shown by the figures cited in Lister this well-known form cannot be mistaken, nor its colour varieties *rufus*, Linn., and *albus*, Müll. in Litt. of the 12th edition of the 'Systema.' According to Collinge (Conchologist, ii. 1892, p. 59) Pollonera identified the British form with the *A. empiricorum* of Férussac, and held it distinct from the *L. ater* of Linné, overlooking Linné's reference to Lister, but no other malacologist has subscribed to this opinion.

HELIX GOTHICA.
The diagnosis of this species might apply equally to either *Pyramidula rotundata* (Müll.) or *P. ruderata* (Studer), whilst the young stage of *Helix lapicida*, Linn., has also been suggested.

As previously mentioned two examples of *P. ruderata* are in the collection, but there is no means of connecting them with Linné's diagnosis, consequently the name cannot be used.

*HELICELLA (HELIX, L.) ITALA (4).
Linné's number in his own handwriting still visible on one of the specimens places the identity of this species beyond doubt.

*COCHLICELLA (HELIX, L.) BARBARA.
Hanley (Ipsa Linnæi Conch. p. 384) states that Dillwyn identified this form with the *Bulimus acutus* of Müller and that the supposition was confirmed by the presence of specimens in the Linnean cabinet that alone agreed with the author's diagnosis. Unfortunately Hanley overlooked the fact that Dillwyn (Cat. ii. p. 956) quotes Müller's *Helix acuta* for the English shell and that under *Helix barbara* (p. 960) he merely criticises Chemnitz's supposition that *H. carinula* might be the species meant, and proceeds "but the description answers better to a diminutive specimen of *H. acuta*." Dillwyn, therefore, made no definite statement on the subject, and consequently one is not surprised to find in the Hist. Brit. Moll. of Forbes and

Hanley the Linnean name is only quoted as "probably" a synonym for Müller's *H. acuta*. Linné's description, he unfortunately quotes no figure, leaves one in doubt whether his specimen may not have been one of the smaller, closely allied species such as *ventricosa*, for he describes it as "Hordei semine paulo major."

Müller makes no allusion to Linné's species, and we consider that in all probability the specimens of *acutus* now in the Linnean collection had been received from Müller, and that Linné's name owing to its uncertainty must be allowed to lapse.

HYGROMIA (HELIX, L.) HISPIDA (1).

The specimen in the Linnean collection that corresponds with the description is, as Hanley points out (p. 368), identical with the *H. concinna* of Jeffreys.

It now forms one item of the little packet marked "No. 40" of those we believe Müller sent to Linné. It may have become enclosed in the packet by error, for Taylor (Monograph, iii. 1916, p. 17) states that though he saw it in the collection thirty years before, he failed to find it when he looked in company with Mr. Roebuck in 1914, and Hanley does not mention its enclosure in paper.

Whether this particular specimen be a Linnean type or not there seems no reason for displacing the name which so many authorities from Müller onwards have attached to the form that now bears it.

*HELICIGONA (HELIX, L.) LAPICIDA (4).

The identity of this species does not seem ever to have been called in question.

ARIANTA (HELIX, L.) ARBUSTORUM (7).

The interpretation of this species also has met with universal acceptance. It may be noted in passing that the reference given in the 10th and 12th editions of the 'Systema' to "List. . . . conch. i. n. 52" is wrong, no such number existing in that work: it is corrected by Gmelin in his edition to "53," which is correct. The further reference to "Argenv. conch. t. 32. f. 8" is quite wrong, the figure in question depicting *H. nemoralis*: this citation is rightly omitted by Gmelin.

HELIX GRISEA.

Although Hanley (p. 378) found the box in the Linnean cabinet so marked to be filled with examples of *Helix aspersa*, Müll., he does not venture to advocate the adoption of the name for Müller's species, although Dillwyn (Cat. ii. p. 943) does. Turton in his translation of Gmelin's edition of the 'Systema' (vol. iv. p. 530) says of *grisea* that it "resembles *H. pomatia*."

Linné's cited figure for his *grisea* in Gualtieri (Index Test. Conch. pl. i. f. C) so inscribed in his own copy of that work, is obviously a *pomatia*, whilst the next figure on the plate (E) which represents *H. aspersa*, has not been marked by Linné, who also when citing correctly for *pomatia* "Argenv. t. 32. f. 1," omits all reference to f. 2 & 3 which are good figures of *aspersa*.

We think, therefore, that he was unacquainted with the later shell. As already mentioned, among the examples of *aspersa* in the collection is one with the remains of a label (Linné always wrote numbers on his specimens), and it seems possible that some if not most of these specimens were received from Müller.

HELIX POMATIA (3).

This is another of those species concerning which there has never been any question, the figures instanced leaving no room for doubt.

*HELIX NEMORALIS (26).

Hanley, we consider, was quite correct in his decision that Linné's species was that which now passes under the name. The reference to "Lister conch. no. 54," where the figures are unmistakable, is correct in the 10th edition of the 'Systema'; but by error the number has been altered in the 12th edition to "53," though this is corrected by Gmelin in his edition.

Westerlund's contention (Fauna Sveciæ, i. 1873, p. 101), that the *H. nemoralis*, L., is the *H. hortensis*, Müll., because the latter form alone he states is met with in Öländ, where Linné appears to have first observed banded snails of this description (Öländska Resa, 1745, p. 127), seems to us beside the mark. Linné's name anyhow dates from the 10th edition of the 'Systema' (p. 773), where the extended habitat of "Europæ" is given, but furthermore Linné in the 'Öländska Resa' cites "Petiv: mus. 5. n. 14" and the latter quotes the figures in Lister's 'Hist. Conch.' i. no. 54, which as already noted are unmistakably *H. nemoralis*.

That Linné did not discriminate between *nemoralis* and *hortensis* is probable, but this was rectified by Müller, from whom possibly some of the specimens in the collection may have come.

*HELIX LEUCAS.

Hanley records (p. 361) finding in a paper certain specimens of immature *Helix pisana*, Müll., which in his opinion coincided with Linné's description of his *H. leucas* and which he thought were in all probability the originals. Two adult and seven immature individuals of *H. pisana*, Müll., are present in the collection to-day but no trace of the paper in which according to Hanley some of the latter were preserved. These specimens may have come from Müller. Linné's diagnosis is not sufficiently clear to enable definite pronouncement to be made, and the name cannot, therefore, well be revived in lieu of Müller's better-known one. It is of interest at the same time to note that Beck (Index Moll. 1837, p. 14) queries under his *Theba leucas* "an *H. pisana*, Ehrbg.? Sav. Egpt. m. ii. 15–16?" The figures thus indicated are undoubted *H. pisana*, Müll., whose species, however, follows next as a distinct one in Beck's list.

HELIX OCTONA.

Müller (Verm. Hist. ii. p. 150) makes this a synonym of his *Buccinum acicula* regardless of the fact that Linné described the species as having "apertura subrotunda," whilst of his own he states "apertura oblonga seu fusiformis."

Nilsson (Hist. Moll. Svec. 1822, p. 92) calls it a *Paludina*, and says it is not dissimilar from Draparnaud's *Cyclostoma acutum*. Hanley (p. 381) agrees with this conclusion. The cited figure (Gualtieri, pl. vi. f. BB), however, suggests the fry of *Limnæa glabra* (Müll.) with which it has been identified by both Pennant (Brit. Zool. iv. 8vo. ed. p. 138, with a ?) and Fleming (Hist. Brit. Anim. p. 274). Pulteney included it in his "Catalogues," but Rackett in the later edition eliminates it on the ground that it is not English.

Linné's name, therefore, cannot well be connected with any of our known species and must remain in abeyance.

HELIX SUBCYLINDRICA.

This also was included by Pulteney in his "Catalogues," but rejected by Rackett as "not of English growth." Dillwyn (Cat. ii. p. 952) and Moquin-Tandon (Hist. Moll. France, ii. p. 304) identify this with Müller's *H. lubrica*, although the habitat is given by Linné as "in aquis dulcibus Europæ borealis." Hanley (p. 379) gives as his opinion that only *Truncatella Montagui* of Lowe [= *T. truncata*, Mont.] agrees with the description of the shell, forgetting that *Truncatella* is a southern not a northern form.

Possibly Linné's shell was the fry of some freshwater form. Anyhow the name will have, we consider, to be left out of account.

PUPILLA (TURBO, L.) MUSCORUM (1).

The identification of this species rests mainly on tradition, Draparnaud alone having applied the name to a different form from that which generally bears it.

There is an example, noted by Hanley, of an edentulous specimen in the Linnean collection that alone accords as he says with the description, but this is in packet "N. 44" of those we now believe to be of Müller's sending. Müller be it noted (Verm. Hist. ii. p. 105) also describes the species, which he puts under *Helix*, as "Apertura edentula," and the name can, we think, be accepted on Müller's confirmation.

Balea (Turbo, L.) perversa (10).

Nothing in the description distinguishes the currently accepted interpretation of this species from the young form of one or two species of *Clausilia* and tradition and the occurrence of undoubted specimens in the Linnean collection alone support its identity. Müller took it for the young form of *Clausilia rugosa*, Drap., as shown by his description of the clausium (Verm. Hist. ii. p. 119). We would propose to retain the name for the species which has so long borne it, although Draparnaud's trivial name of *fragilis* has been almost equally used in the past.

***Succinea (Helix, L.) putris.**

The figure cited from Lister and the specimen in the collection leave no doubt as to the identity of this species. As Hanley points out, and as already noted, examples of *S. pfeifferi*, Rossm., are also present in the collection and it is possible that Linné did not discriminate between the two forms.

Acroloxus (Patella, L.) lacustris.

Although the form which to-day bears this name is not in the collection whilst examples of Müller's *Ancylus fluviatilis* are, we do not agree with Hanley that the latter is Linné's species, but regard them as part of the Müllerian contribution to the collection, since the ten individuals were included in packet "No. 53."

Linné's definition is "testa integerrima ovali membranacea, vertice mucronato reflexo" (Faun. Svec., ed. 2, p. 534), showing that the oval shape and prominent mucro had struck him. Contrast this with his description of *Patella pellucida*, which in form comes nearest to Müller's *fluviatilis*, and which follows in the 'Systema' (10th ed., p. 783), where the term used is "obovata." "Ovali" on the other hand is applied to elongate forms such as *Patella compressa* and *P. lutea*. Then the locality "Lacubus . . . foliis insidens subaquis" is more applicable to *Acroloxus* than to Müller's species, which is chiefly found in swiftly running water, though at times the two have been taken together on water plants.

Lister's figure cited is of course more applicable to Müller's species, as also is the habitat he quotes, but in this respect Hanley's caveat (p. 6) as to Linné's citation of somewhat similar figures must be borne in mind. The same remark applies equally in the following.

***Limnæa (Helix, L.) auricularia (3).**

Linné's diagnosis "spira brevissima apertura ampliata" is more convincing than the figures pressed into his service. These are various. Thus "Lister angl. t. 2. f. 23" seems an inflated form of *L. pereger* (Müll.). "Argenv. conch. t. 31. f. 7. bona" shows two shells on either side of the "7" which will pass for *auricularia*, whilst the one to the left of them is an inflated *pereger*. "Klein ostr. 54. t. 3. f. 69" is a bad copy of the figure in Lister's 'Hist. Anim. Angl.' pl. ii. f. 21 (and is Klein's type of his *Auricularia stagnorum*) or the figure already cited by Linné as his *Helix stagnalis*. The "Acta Helv. 5. t. 3. f. 27, 28" is evidently *auricularia*.

The specimens in the collection include *auricularia* vera (3) and inflated forms of *pereger* (4). Müller's segregation of the latter is therefore correct.

HELIX LIMOSA.

Nilsson (p. 72) identified this with *Limnæa truncatula* (Müll.), whilst Hanley (p. 387) conjectures it may have been a narrow form of *L. pereger* (Müll.) and Reeve (Land & Fresh-w. Moll. Brit. Is., p. 157) adopt the name for that species.

The figure cited by Linné in the 12th edition of the 'Systema' (p. 1249) from Gualtieri (pl. v. f. H) and marked on the margin of the plate in his own handwriting, is suggestive of the fry of possibly *Succinea putris*. In the 'Fauna Svecica' first edition (p. 367. no. 1314) it is described as "anfractibus quinque," an item omitted in both the 10th and 12th editions of the 'Systema'; whilst the final "Descr." reads "Præcedentibus duabus duplo minor; operculo etiam clauditur."

The two preceding species of the 1st edition of the 'Fauna' are named in the 2nd *Helix vivipara* and *Helix tentaculata*. Linné's *Helix limosa* was therefore an operculate†, which cannot now be identified, so that the name must be allowed to lapse.

HELIX BALTHICA.

The "rugis elevatis" noted in the description of this species (Fauna Svec. 2nd ed., p. 532) and amplified in the "Descr." to "superficies testæ striis elevatis remotis versus aperturæ marginem oblique descendentibus" does not accord with a *Limnæa*, to which genus Nilsson (pp. 64–65) refers it.

The form appears indeterminate and likely to remain so.

*LIMNÆA (HELIX, L.) STAGNALIS (1).

By diagnosis and figures the identity of this species is confirmed. Also that Linné's *H. fragilis* is a synonym.

*PLANORBIS (HELIX, L.) CORNEUS (4).

This is, fortunately, one of those species concerning whose identity there never has been any doubt.

*PLANORBIS (HELIX, L.) PLANORBIS (8, including 3 probably sent by Müller as examples of his *P. umbilicatus*).

Why there should have been any question concerning this form it is difficult to understand, for the reference to Lister's figure (Anim. Angl. pl. ii. f. 27) clearly establishes its identity with the *Planorbis umbilicatus* of

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† This we find has already been pointed out by Mörch (Synop. Moll. Daniæ, 1864, p. 43, note).

Müller. Müller includes in his synonymy (Verm. Hist. ii. p. 160) the *Helix complanatus* of Linné, but three pages further on queries whether the latter be not the same as his own *P. nitidus*, a point we discuss later.

Linné's name for this species having priority must be restored to literature.

PLANORBIS (NAUTILUS then TURBO, L.) CRISTA.

Despite Linné's doubt as to the zoological position of this form, referring it as he does first to *Nautilus* and then with the changed trivial name of *nautileus* to *Turbo*, there never has been any hesitation as to the species meant.

PLANORBIS (HELIX, L.) VORTEX (1).

The figures referred to in Lister and Gualtieri show clearly the group to which Linné's species belongs, and the description in the 'Fauna Svecica' (2nd ed., p. 527, no. 2173), "margo testæ in illa extra testam exseritur, at in hac ipse testæ angulus est acutus," points to the correctness of the accepted interpretation, which is further borne out by the single example in the collection.

PLANORBIS (HELIX, L.) SPIRORBIS.

No figures are cited by Linné and the description is rather too vague to enable one to accurately discriminate the species. Linné's specimen must have been bleached since it is given as "Testa alba." No example is in the collection.

Müller, who adopts the species (Verm. Hist. ii. p. 161), further defines it as having "anfractus quatuor . . . margine tereti absque ulla carina. Apertura rotundata sublabiata; margo saltem summus intus albus, crassiusculus." This seems to indicate the commonly accepted species. The closely allied *rotundata*, Poiret, has a whorl more and a more angular mouth.

*PLANORBIS (HELIX, L.) CONTORTUS.

Although no figures are cited, the description in the 'Fauna Svecica' (2nd ed., p. 528, no. 2181) and the former presence, vouched for by Hanley, of a specimen in the collection, that, however, we have not seen, serve to establish the identity of this species with the commonly accepted form.

PLANORBIS (HELIX) COMPLANATUS.

Hanley's arguments and conclusions concerning this species are correct, given the fact that he in common with most other observers of his period identified Müller's *nitidus* with Lightfoot's *fontanus*, whereas it is now known, and we have the authority of Dr. A. C. Johansen for the fact, that all Müller's specimens belong to the form called *lacustris* by Lightfoot and placed to-day in the genus *Segmentina* of Fleming. Some of Müller's specimens are not, Dr. Johansen states, well preserved and this led

Dr. Gwyn Jeffreys to conclude from his observation of them that both species were included in Müller's *nitidus*. Linné's description "subtus plana omnino, sed parum cava versus centrum" is more applicable to Lightfoot's *fontanus* than to his *lacustris*.

Linné's name must, we think, be restored and the two forms be respectively known as *Planorbis* (*Hippeutis*) *complanatus* (Linn.) and *Segmentina nitida* (Müll.). As previously mentioned, three individuals of this last are now in the collection, given, as we believe, by Müller.

PHYSA (BULLA, L.) FONTINALIS &
PHYSA (BULLA, L.) HYPNORUM
are recognizable from the descriptions in the 'Fauna Svecica' (2nd ed., p. 523, no. 2160 and p. 522, no. 2159 respectively). No example of either is in the collection, but no doubts have ever been raised concerning their identity.

PALUDESTRINA (HELIX, L.) STAGNALIS.

Linné in the 12th edition of the 'Systema' (p. 1248, no. 697) introduced the name "*Helix stagnalis*" for Baster's *Turbo stagnalis.* As Hanley points out, he afterwards noticing that he had already used the name for the well-known pond-snail, altered it in manuscript in his own copy to *Basteri**, whilst Gmelin (Syst. 13th ed., p. 3653, no. 119) changed the trivial name to *stagnorum*.

Baster's species has been held to be identical with Pennant's *Turbo ulvæ*, and consequently his name being prior has been used in lieu of Pennant's. We have shown, however (Proc. Malac. Soc. Lond. xii. 1907, p. 124), that the species abounding at Baster's locality was identical with a form considered at the time on the authority of Dr. Johansen to be the *Paludina minuta* of Totten. Totten's species, however, proves to be quite different, and there is now reason to believe that we are here dealing with the *Turbo ventrosus* of Montagu, vera, the form commonly passing under the name being distinct. But this requires further research.

BITHYNIA (HELIX, L.) TENTACULATA (19, wrapped in a scrap of paper bearing German print).

We agree with Hanley that the description in the 'Fauna Svecica' (2nd ed., p. 531) and the reference to Lister's figure sufficiently determine this species to be the form commonly accepted as such.

In the first edition of the 'Fauna' (p. 376, no. 1313) Linné contrasts it "cum præcedenti" (No. 1312) the *Helix vivipara* of the 2nd edition, but neglected to make the necessary correction in the 2nd edition where five other species have been intercalated.

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* Müller, Verm. Hist. ii. p. 182 note, also calls attention to the double use by Linné of *Helix stagnalis*.

Linné was most unfortunate in his selection of further illustrations for the 12th edition of the 'Systema,' those from Bonanni, Lister's 'Hist. Conch.' and Klein's copies of these last, being all well-marked marine trochoids; whilst the reference to Adanson is hopelessly wrong.

*VIVIPARUS (HELIX, L.) VIVIPARA (14).

Linné's description "H. testa imperforata" definitely determines which of the two closely allied forms he had in mind, but of the figures referred to, Lister's "exerc. 2. p. 17. t. 2 [f. 5]," which is Müller's *fasciata*, shows that he had not discriminated between them. Any possible uncertainty is, however, set at rest by our discovery the other day that two of the specimens bore the number "603," that of the species in the 10th edition of the 'Systema' in the master's own handwriting †.

There are now, in the same glass-topped box, two specimens of *fasciata*, obviously from quite a different gathering, and these we are inclined to think may have been sent him by Müller, whose separation of the two forms is correct, and whose name has priority over *contecta*, Millet, which has of late been generally used.

TURBO REFLEXUS.

We do not agree with Hanley that because examples of *Pomatias elegans* (Müll.) were found in the box marked for Linné's *Turbo reflexus* that Dillwyn's surmise was correct. Like other Müllerian species they may have come from that author.

Linné's phrase "apertura reflexa" and "Habitat in Europa australi" dispose to our mind of the possibility of its identity with Müller's *elegans*, but we decline to speculate on its correct interpretation.

*THEODOXUS (NERITA, L.) FLUVIATILIS & LACUSTRIS.

There is, fortunately, no hesitation as to the correct ascription of Linné's name *fluviatilis* to the form that has always borne it; whilst we further agree with Hanley in believing that the *lacustris* was only a variety of the same polychromatic shell.

*UNIO (MYA, L.) PICTORUM.

Although the diagnosis is too meagre to show which of the two forms *pictorum* or *tumidus* was meant, the figure first cited by Linné (Lister ang. app. t. 1. f. 4) is that of the commonly accepted *pictorum*, whilst the inscribed specimen in the collection certainly is. There is an individual also in the cabinet of *tumidus* but without any history. The added reference in the 10th edition of the 'Systema' to "Bonan. recr. 2. t. 41," which is a copy of

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† After this paper was written and handed in Mr. J. W. Taylor has placed on record (Naturalist, 1918, p. 249) that this fact had been observed by him and Mr. Roebuck, to whom belong the credit of having detected specimens that escaped us some years ago.

Lister's "Anim. Angl., pl. ii. f. 30," rather suggests *tumidus*. Retzius, however, as next reviser separated the two species on lines ever since followed and no objection has ever been raised to his decision. It is commonly overlooked, however, that the name *Unio* was Linné's own, as Retzius acknowledges, its characters having been communicated to him by Linné's pupil Acharius.

*MARGARITANA (MYA, L.) MARGARITIFERA (1).

No uncertainty has ever existed concerning the identification of this well-known species, supported as it is by Lister's figure (Anim. Angl. append., pl. i. f. 1).

*ANODONTA (MYTILUS, L.) CYGNEA (1).

Of the two species now once more recognized as valid, the inscribed and numbered specimen in the collection with the figures cited (Lister angl. app. t. 1. f. 3 and Gualtieri t. 7. f. F, the latter written against by Linné himself in his copy of the work) quite establish its identity.

The further quotation of Lister "conch. t. 193. f. 8" in the 10th edition of the 'Systema' (p. 706) should, as Hanley remarks, be "153," but both Linné and Hanley overlooked the fact that the figure in question is a reprint of Lister's Anim. Angl. append., pl. 1. f. 2 adduced by Linné in illustration of his *anatinus*. This same figure copied by Klein (Ostr. t. 9. f. 26) is correctly cited by Gmelin under *anatinus*.

The correct reference to Lister's Conch. should have been "156" which is the copy of the "app. t. 1. f. 3."

*ANODONTA (MYTILUS, L.) ANATINA.

Lister's figure (Anim. Angl. append., pl. i. f. 2) originally cited in the first edition of the 'Fauna Svecica,' with the enlarged description in the 'Systema' (10th ed., p. 706, no. 219) and in the second edition of the 'Fauna Svecica' (No. 2158) convince us that the customary identification of this species is correct. The figure in Gualtieri added in the 12th edition of the 'Systema' may or may not have been intended for a *Unio*, but lacks any hinge-teeth. This may have caused Linné to include it and possibly may account for his puzzling observation in the 10th edition of the 'Systema'—"similis Myæ pictorum, sed fragilior & cardine distinctissimus."

We do not agree with Hanley that Lister's "f. 2" shows "an ordinary example of the *Anodonta cygnea*," nor with his selection of the specimen figured by him in illustration, which, as the umbonal rugæ show, belongs to the genus *Pseudanodonta*, Cf. *P. gratelоupiana* (Gassies) or *P. normandi* (Dupuy). It is only fair to add, however, that this genus had not in his days been separated off from *Anodonta*.

*SPHÆRIUM (TELLINA, L.) CORNEUM.

Happily, though we were unable to trace the specimen in the collection, this is another of the undisputed species and calls for no comment.

The *Exogoneæ*. By W. A. Haswell, M.A., D.Sc., F.R.S., F.L.S., Emeritus Professor of Biology, University of Sydney.

(Plates 17 & 18, and 2 Text-figures.)

[Read 5th December, 1919.]

INTRODUCTION.

In the introductory part of his 'Recherches sur les Syllidiens' (1913), Malaquin has embodied a very complete history of the development of our knowledge of the family. Malaquin's own work is certainly of the first importance in connexion with this development, on account both of the original observations recorded therein and of the systematising of work previously published. But Malaquin concerns himself almost exclusively with the *Eusyllidea*, the *Syllidea*, and the *Autolytea*, having few actual observations on the *Exogoneæ* to record: and out of three hundred and fifty or more figures with which the work is illustrated only three refer to the *Exogoneæ*. Thus in his account of the alimentary canal, the nephridia and gonads, and the development, it is almost assumed that the *Exogoneæ* resemble the larger forms but for the difference in size. And this is quite true up to a certain point. But beyond that, in a number of important details the *Exogoneæ*, or certain of them, present very special features.

The material on which the following observations were based was collected almost exclusively in Port Jackson, either between the tidal limits or a little below low-water mark.

In the structural part I have not given any general account of the morphology; but have confined myself to certain sets of organs with regard to which the *Exogoneæ* exhibit peculiarities of a strongly-marked character—the integumentary and related glands, the alimentary canal, and the nephridial and reproductive organs.

In the account of the embryology which follows there are various obvious gaps. I hope to fill some of these later by the adoption of certain methods which I have not hitherto utilized; the detailed history of the cell-lineage, for example, can only be followed out by keeping large numbers of living specimens under observation. As it is, however, the study of my extensive collection of fixed material has resulted in the observation of a number of facts which have hitherto, so far as I have been able to ascertain, been unrecorded.

I have pleasure in acknowledging my great indebtedness to Professor McIntosh for literature, specimens, and information furnished; to Professor Benham for the loan of his copy of Malaquin's work; and to Dr. Pierantoni for sending me at my request a copy of his paper, "La gestazione esterna," which was otherwise inaccessible to me. For assistance in collecting specimens I owe thanks to Professor S. J. Johnston, Mr. Thomas Whitelegge, and Miss B. M. Somerville.

SYSTEMATIC.

The only published work in which there is any reference to the *Exogoneæ* of the Australian coasts is Augener's 'Polychæta' of the 'Fauna Sudwest Australiens.' In this the following are described:—

Exogone heterochæta, McInt.
Sphærosyllis hirsuta, Ehl.
Sphærosyllis perspicax, Ehl.
Grubea kerguelensis, McInt.
Grubea quadrioculata, n. sp.
Grubea furcelligera, n. sp.

EXOGONE FUSTIFERA, n. sp. (Plate **17.** figs. 1–6.)

This is a larger form than the European *E. gemmifera*, reaching a length of 7 mm. as compared with the 3 to 4 mm. of the latter. The maximum number of segments observed to occur was 43 as against 33 in *E. gemmifera*; but one complete specimen had only 32.

The palpi are completely united, but separated ventrally by a median cleft. The almost completely semicircular outline of the united palpi may be broken by a slight median notch, but this is frequently indistinguishable. The prostomium and peristomium are very closely united together and scarcely distinguishable superficially. The three prostomial tentacles are nearly equal in length, the median one slightly longer than the other two, projecting slightly beyond the end of the palpi. They are very slender except towards the end, where there is a marked dilation. The eyes, as is usual in the genus, vary greatly in size in different phases.

The peristomium bears a pair of extremely rudimentary button-like tentacles, which are placed comparatively far forwards, so that in fixed specimens they may be on a level with the interval between the anterior and posterior eyes. Close to each is a ciliated pit.

The parapodia (Pl. **17.** fig. 2) are short—in length less than half the breadth of the body, narrowed distally, the extremity simple, rounded. In each are normally a single stout aciculum and five setæ, of which the most dorsally and the most ventrally situated are simple, the rest compound. The dorsal simple seta (figs. 4, 5) ends in a curved conical extremity which may be obscurely notched close to the apex, the notch sometimes, though rarely, bearing a fine hair-like appendage. Often this seta is absent in some of the parapodia or does not project on the surface. The ventral (fig. 6) is more strongly hooked, and is bifid at its apex. The three compound setæ (fig. 3) have the terminal appendages greatly reduced, in the form of simple slender curved rods without serrations or teeth. Sexually ripe individuals have in addition bundles of long capillary natatory setæ on the dorsal side of the parapodia of most of the segments. As in other Syllids, the setigerous sac in which new setæ are developed is quite separate from the bundle of mature setæ, and attached firmly to the aciculum on its dorsal side.

The dorsal cirri are greatly reduced, shorter than the parapodia, oval or spherical in shape. The second segment is always devoid of dorsal cirri. The ventral cirri are also rudimentary, but more cylindrical in form. The anal cirri are longer than the parapodia, slender and cylindrical, not swollen at the ends.

In the retracted condition of the proboscis the pharynx runs through the first three segments, the proventriculus lies in the fourth and fifth, and the ventriculus and cæca are situated in the sixth.

Exogone fustifera is by far the commonest of the Port Jackson *Exogoneæ*, and occurs abundantly among finely branched Algæ of all kinds about low-water mark. I also found it in Broken Bay among Algæ and Sponges growing on the piles of a wharf; and in material collected at Port Stephens by Prof. S. J. Johnston.

Viguier (**34**) * identifies the species of *Exogone* which he found most abundant in the Bay of Algiers with that observed by Pagenstecher (**26**) at Cette, and named by him *E. gemmifera*. Viguier was not in any doubt on this point. He writes :—" C'est bien le type étudié par cet auteur que j'ai pu observer à mon tour." But a comparison of the descriptions and figures of the two authors leaves some doubt of the correctness of the identification. Viguier states with regard to the tentacles : " Elles sont legèrement renflées un peu au-dessous de leur base, et décroissent jusqu'au sommet, qui est arrondi et muni de quelques petites soies raides " (p. 77); while Pagenstecher refers to the same appendages as " nur wenig Kolbig anschwellende Fühler," and his figure represents them as *distinctly* swollen at the ends. I think it probable that Pagenstecher's *E. gemmifera* is Œrsted's *E. naidina* (**25**) and that Viguier's *E. gemmifera* (Pagenstecher), though identical with Claparède's *E. clavigera*, as Viguier himself maintains, is not Pagenstecher's species.

Should this suggestion prove to be correct, it would be to *E. naidina* (Œrsted) that *E. fustifera* would most closely approximate rather than to *E. clavigera* (Claparède).

EXOGONE VERRUGERA, *Claparède*. (Plate **17**. figs. 7–10.)

Pædophylax veruger, Claparède, **2**, p. 213, pl. 12. fig. 3.

A second species of *Exogone* occurring in Port Jackson is nearly related to Claparède's *Pædophylax verrugera* from the Gulf of Naples. Like the preceding it is a small form, and does not exceed 7 mm. in length. There are about 37–40 segments.

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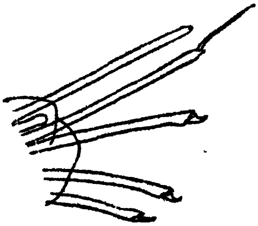
* The thick figures refer to the Bibliography at the end.

The palpi are completely united, without any median notch (even in the embyro) and are comparatively long, so that in the living animal, when fully extended, they may be three times the length of the prostomium and peristomium together. The tentacles are usually reduced to three similar oval rudiments, but in some the median tentacle is a good deal longer than the others. The single peristomial tentacle is very small, though not so rudimentary as in *E. fustifera*.

The simple seta on the dorsal side of each parapodium (fig. 9) has the curved terminal part tapering to a fine point close to which is a small denticle. There are five compound setæ (fig. 8), all of which have terminal appendages of the normal kind, that of the first (most dorsal) (text-fig. 1) long and slender, while those of the others, though completely formed, are quite rudimentary. The most ventral seta is usually simple, curved at the end and bidentate, like the corresponding seta in *E. fustifera*. The aciculum (figs. 10 A, 10 B) is curved at the end and slightly expanded. Both the dorsal and the ventral cirri are small and approximately oval like the tentacles.

Text-fig. 1.



Setæ of *Exogone verrugera*.

Dorsal cirri are always present on the second segment. The eyes in most cases have the appearance represented in fig. 7. In one specimen they are both large and irregularly shaped, the anterior pair being rather the larger; in another the posterior pair of eyes had the pigment remarkably drawn out into a long narrow process projecting backwards into the peristomium behind the ciliated groove. In several others the lenses of both the anterior eyes are produced into horn-like pointed bodies.

The median tooth, when the proboscis is retracted, lies in the first setigerous segment. The gizzard is much more elongated than in *E. fustifera*, extending from the fifth to the seventh segments in the retracted condition, and containing about 25 rows of muscle-columns.

In most respects this species, which is fairly common in Port Jackson, approaches very near Claparède's *E. verrugera*. But the difference in the palpi seems to be very marked—those of *E. verrugera* being, to judge from Claparède's figure, distinctly notched terminally.

EXOGONE HETEROSETOSA, *McInt.* (Plate **17**. figs. 11–17.)

Exogone heterosetosa, McIntosh, **20**, p. 205, pl. 33. figs. 15 & 16; pl. 34 A, fig. 11.
Exogone heterosetosa, McInt., Ehlers, **8**, p. 51, pl. 3. figs. 61–65.
? *Exogone heterosetosa*, McInt., Gravier, **15**.
Exogone heterochæta, McInt., Augener, **1**, p. 247.

The specimens of this species which I have before me are all small worms, not more than 4 mm. in length. There are about 40 segments.

The palpi are elongated, longer than the prostomium and peristomium, closely united, but separated distally by a distinct notch which is well marked in late fixed embryos. The unpaired tentacle extends as far as, or slightly beyond, the extremity of the palpi. The lateral tentacles are not more than half the length of the median. As regards the peristomial tentacles and the dorsal cirri, there are two types. In the one all these appendages take the form of stout cylinders. In the other they are all oval. The dorsal cirrus of the second segment in all my specimens is absent. The ventral cirri are smaller than the dorsal. The anal cirri are long and tapering, similar in shape and size to the median tentacle.

Of the setæ the most dorsally placed (Pl. **17**. fig. 12) is a simple, curved, pointed form similar to the corresponding structure in *E. fustifera*. The next (figs. 13 and 14) is a compound seta of a characteristic form. The shaft is expanded at the end into a broad plate with an oblique, finely crenulated edge. With this articulates the terminal appendage, which usually takes the form of a very thin triangular plate sometimes replaced by a slender tapering rod. The remaining compound setæ (figs. 15 to 17), three or four in number, are all similar to the corresponding setæ of *E. verrugera*, with small but well-formed appendages, or one may partake to some extent of the special characters of that just described. Sexually mature specimens have in addition bundles of capillary setæ on the segments from the twelfth or thirteenth backwards.

In the most complete specimens the proboscis is partly protracted and the proventriculus lies in the 3rd, 4th, and 5th segments. In another, apparently retracted, it lies in the 4th, 5th, and 6th. The proventriculus is similar to that of *E. verrugera*, and has about 20 rows of muscle-columns.

Augener refers to *Exogone heterochæta*, McInt. (obviously a slip for *E. heterosetosa*) as one of the commonest species in South-west Australia, and states that his determination of the Australian specimens was confirmed by comparison with southern-antarctic specimens. But I am not sure that he has not confounded this species with the one which I have set down tentatively as *E. verrugera*.

In *E. heterosetosa* the presence of the notch between the palpi (which is well shown in McIntosh's original figure), and the absence of the dorsal cirri of the second segment appear to be constant features (recognizable even in attached larvæ) distinguishing this species from the last, apart from the differences in tentacles and setæ.

E. heterosetosa occurs in Port Jackson much more sparingly than *E. fustifera.*

GRUBEA PUSILLOIDES, n. sp. (Plate **17.** figs. 27, 28.)

This small Syllid, not much over 2 mm. in length in the case of the largest specimens, is not uncommon in certain situations between tide-marks in Port Jackson. It is nearly allied to *G. pusilla* (Dujardin); but, unless the published accounts err in certain important particulars, it is quite distinct from that species, which has been found hitherto only in the Mediterranean and in the English Channel.

In describing *G. pusilla* Dujardin fell into the error of regarding it as hermaphrodite, the rod-like bodies developed in glands in the dorsal cirri being supposed by him to be spermatozoa. This misconception was corrected by Claparède (**3.** p. 44: **4.** p. 89) who pointed out the true nature of these bodies. More recently Baron de St. Joseph (**31.** p. 79) has observed males with natatory setæ and spermatozoa and females with embryos on the ventral side.

The most interesting point about the Australian species is that, whereas its very near relative was originally supposed (erroneously) to be hermaphrodite, and proved when critically examined to have the sexes separate like the vast majority of the Polychæta, the new form actually has the sexes united.

The details of this condition will be given in the general part of this paper.

A complete specimen of *Grubea pusilloides* is about 2 mm. long and contains some 25 to 33 segments. The palpi, united dorsally at their bases, are separated distally by a cleft which may be widened to a distinct gap: they are approximately equal in length to the prostomium. The prostomial tentacles are dilated at the bases, narrow distally, tipped with non-motile cilia: they project a little distance beyond the ends of the palpi, the median tentacle being slightly longer than the others. There are two pairs of small eyes, the anterior pair the larger. The peristomial tentacles are similar in character to the prostomial, the upper of the two on each side being somewhat longer than the lower.

The parapodia (see text-fig. 2, p. 235; Pl. **17.** fig. 28) are simple, pointed, their length about a third of the breadth of the body. Of the setæ, in all but the first few segments the one situated most dorsally is simple, almost straight, gently curved towards the end, with a row of very minute fine teeth along its concave border *. All the rest are compound, with long and slender terminal appendages.

The dorsal cirri are, like the setæ, very similar to those of *G. pusilla.*

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* The seta in *G. pusilla* corresponding to this is described nearly as above by De St. Joseph, and the figure he gives agrees well with the corresponding seta in *G. pusilloides.* But he erroneously refers to it as *ventral* instead of *dorsal.*

They are sub-cylindrical, relatively thick, truncate distally, the edge of the terminal face finely crenulate and with a few long non-motile cilia. The most striking feature of the dorsal cirri is the presence in each of a pair of spindle-shaped bundles of thread-like objects situated towards the distal end, each enclosed in a sac which is produced into a narrow prolongation or duct ending at the free end of the cirrus. These, as pointed out by Claparède, are the equivalents of the "glandes à bâtonnets" (rhabdite glands) found more deeply placed in some allied Syllids such as *Sphærosyllis hystrix*. In close opposition with these is a rounded sac with granular contents, having like them a prolongation or duct opening at the free end of the cirrus. The ventral cirri are short, cylindrical, not nearly so long as the parapodia. The anal cirri are like the tentacles in shape and are half as long again as the dorsal cirri ; there is no unpaired process between them.

The proventriculus in the retracted state of the proboscis lies in the 4th and 5th or 5th and 6th segments. Its walls contain about twenty rows of muscle-columns.

GRUBEA KERGUELENSIS, *McIntosh*. (Plate **17**. figs. 18–20.)

Salvatoria kerguelensis, McIntosh, **20**, p. 188, pl. 30. fig. 4 ; pl. 33. fig. 1 ; pl. 15 A. figs. 11 & 12.
Sphærosyllis Macintoshi, Ehlers, **8**, p. 46.
Grubea kerguelensis, Augener, **1**, p. 252, text-fig. 37 ; Taf. 3. fig. 23.
? *Grubea limbata*, Claparède, **2**, p. 208, pl. 13. fig. 4.

A species of *Grubea* which is fairly common in Port Jackson corresponds for the most part to Claparède's description and figures of his *G. limbata*, with certain differences, the most important being in the shape of the setæ. I think the Port Jackson species may be the same as one found common in the collections from South-west Australia studied by Augener, and identified by that author with *G. kerguelensis* (McIntosh). I do not think that sufficient grounds for that determination are adduced, but here accept it provisionally. Meanwhile I give some figures of the Port Jackson form which may help to solve the question.

It is to be noted that Claparède gives as one of the differences between his *G. limbata* and his *G. tenuicirrata* that in the latter the second dorsal cirrus is longer than those that follow. But this can only be a matter of degree since in his figure of the former species he represents the second dorsal cirrus as distinctly longer than those behind.

GRUBEA QUADRIOCULATA, *Augener*. (Plate **17**. figs. 21–26.)

Grubea quadrioculata, Augener, **1**, p. 254, text-fig. 38 ; Taf. 3. fig. 31.

This *Grubea*, which Augener found rare in the South-west Australian collections, occurs, also somewhat rarely in my experience, in Port Jackson. It is most clearly distinguishable from the preceding by the absence, in the majority of specimens, of the frontal eyes, and the greater size of the proventriculus.

Augener's fig. 31, though it doubtless represents his material accurately, does not correctly represent the head-end as it appears in living or well-fixed specimens, and I give here a new figure as well as one of the parapodium and the setæ.

The two species here referred to as *G. kerguelensis* and *G. quadrioculata* do not differ very widely from one another. The latter is a larger and more robust form than the former, has a comparatively large proventriculus, and usually only four eyes. But six eyes are present in a considerable proportion of cases.

SPHÆROSYLLIS HYSTRIX, *Claparède.* (Plate **18.** figs. 32–35.)

Sphærosyllis hystrix, Claparède, **3**, p. 45, Taf. 13. figs. 36, 37.
Sphærosyllis hystrix, Marenzeller, **23**, p. 25.
Sphærosyllis hystrix, McIntosh, **21**, p. 156, pl. 59. figs. 3, 4, 8; pl. 70. fig. 1; pl. 78. figs. 11–13.

In describing *S. pirifera* (Ann. Chét.) Claparède refers to a few points of difference from *S. hystrix* previously described by him. The cirri and tentacles he states are relatively shorter and more dilated at the base and always curved or hooked at the ends. Marion and Bobretzky (**24**) regard *S. hystrix* and *S pirifera* as identical or at least not specifically distinct. The nearness of the two forms is emphasized by De St. Joseph. The distinctive character, he states, is the existence of the "glandes à bâtonnets" in *S. hystrix.*

A *Sphærosyllis* which is extremely common in Port Jackson conforms closely to Claparède's account of *S. pirifera* as supplemented by Viguier (Arch. de Zool. exp. et gén., 2 sér., tome ii. (1884)). But it possesses the "glandes à bâtonnets," and should thus, by De St. Joseph's interpretation, be assigned to the older species. This, however, is contradicted by De St. Joseph's statement that in the latter the yellow glands are absent. Moreover Viguier states that *S. hystrix* remains always transparent and does not become encrusted with foreign bodies.

As the Port Jackson form, like the specimens collected by Pierantoni in the Gulf of Naples, frequently possesses both the rhabdite glands and the yellow glands, I have followed the last-named author in his conclusion that the presence of the structures in question or their apparent absence is not to be relied on as a specific distinction. I am inclined to believe that both sets of structures are present in all *S. hystrix* and *S. pirifera* specimens, but that one or other, owing to its physiological or developmental condition, may sometimes not be readily recognizable. As the Australian specimens differ in some minor points from the published descriptions, I think it desirable to describe and figure this common Australian form pretty fully, while still retaining for it for the present the name of *S. hystrix.*

The length of a mature specimen is, on the average, about 5 mm. with a breadth of about ·5 mm. The number of segments varies from about 25 to over 40. The length of the segments is approximately half the breadth. The colour is grey or reddish- or yellowish-grey, and is regulated by the amount of adherent débris. The colour, when present, is due to diffused irregular dots of red pigment.

The palpi, which equal prostomium and peristomium in length, are, as in other species of the genus, closely united together, separated by a median groove and a terminal notch. The distal part is contracted, the narrowing usually taking place rather abruptly; the narrower terminal part is often bent sharply downwards so that it becomes invisible when the animal is looked at from above. Most specimens have the palpi entirely devoid of papillæ, but in a few cases two symmetrically placed pairs of very distinct papillæ are present on the dorsal surface of these appendages. The tentacles are of equal length, scarcely extending as far as the distal end of the palpi. The basal portion of each is dilated, the distal narrow—the dilated and narrow parts being of nearly equal length. Under some conditions, or in some individuals, the dilated parts of the tentacles (and the same holds good of the cirri) become almost spherical and the narrow terminal parts greatly reduced. There are never more than four eyes, the "frontal" pair present in some nearly-related species being absent. The size of the eyes varies greatly, being greatest in individuals with ripe sexual products. The single pair of peristomial tentacles are similar to the prostomial.

The dorsal surface of the peristomium and the segments of the body are ornamented with papillæ. The surface of the body is very usually covered with a layer of granular débris adhering to the surface, and this may completely hide the papillæ, but, when the latter are distinguishable, their arrangement is extremely regular, about fifteen pairs being symmetrically placed on each segment. On the ventral side also papillæ are present, but these are smaller and less numerous than those of the dorsal surface.

The dorsal cirri closely resemble the tentacles in form and size. They are about equal in length to the corresponding parapodia, but may project beyond them. They bear each a small number of papillæ, but these are never so prominent as those on the body and parapodia and are sometimes very obscure. The dorsal cirri of the second setigerous segment were absent in all the specimens examined for them.

The ventral cirri are smaller than the dorsal, and not definitely dilated at the base. The anal cirri do not differ notably from the largest of the dorsal cirri and resemble them with regard to the papillæ. There is no posterior median process, but three pairs of papillæ, rather larger than those on the general surface, lie between the anal cirri.

The parapodia (Pl. 18. fig. 33) are in length about half the breadth of the body, of compressed conical shape. Each bears two prominent papillæ towards its extremity. The single aciculum has its terminal part bent nearly at right angles with the rest of its length in the manner described by Viguier (**34**), by St. Joseph (**31**), and by Pierantoni (**28**). The most dorsally placed seta is simple, gently curved towards the end, and pointed; along the concave edge of its terminal part runs a row of exceedingly small hair-like teeth. The remaining setæ, usually six in number, are all compound and of the same general character, with well-developed, though short, terminal appendages. In sexually matured specimens, but not in females bearing external ova or embryos, there are bundles of long capillary setæ (natatory or puberty setæ) beginning on the 12th to the 14th segment and ending on the 28th to the 35th.

The proventriculus (gizzard), when the proboscis is fully retracted, lies in the fifth and sixth setigerous segments. Its wall contains about 15 rows of muscle-columns. Yellow glands and "glandes à bâtonnets" are both present.

The eggs and embryo are borne in pairs on the ventral side.

SPHÆROSYLLIS PERSPICAX, *Ehlers.*

? *Sphærosyllis kerguelensis*, McIntosh, **20**, p. 206, pl. 29. fig. 5; pl. 33. fig. 10; and pl. 15 A. fig. 22.
Sphærosyllis perspicax, Ehlers, **11**, p. 66, tab. 6. figs. 1–3.
? *Sphærosyllis antarcticus*, Gravier, **15**, p. 12.
Sphærosyllis perspicax, Augener, **1**, p. 250.

The *Sphærosyllis* which I refer to the above-named species is comparatively very rare in my experience in Port Jackson.

Augener found it also rare in the South Australian collection of the Hamburg Expedition to South Australia. It differs from the common form which I have referred to *S. hystrix*, (1) in having the palpi relatively shorter, not produced into such a long narrow anterior prolongation, and beset with well-formed papillæ; (2) in the presence of the third or frontal pair of eyes; (3) in the acicula being straight to the end; (4) in the much greater length of the proventriculus, which extends nearly through four segments, and has about 20 rows of muscle-columns in its walls; and (5) in the embyros being borne on the dorsal side, four on each segment.

SPHÆROSYLLIS HIRSUTA, *Ehlers.*

Sphærosyllis hirsuta, Ehlers, **8**, p. 48, Taf. 3. figs. 58–60.
Sphærosyllis hirsuta, Ehlers, Annelid. d. Valdivia-Exped. Band xvi. p. 66.
Sphærosyllis hirsuta, Ehlers, **10**.
Sphærosyllis hirsuta, Augener, **1**, p. 249.

This species appears to be common in South Australia, but I have not hitherto succeeded in finding it in Port Jackson. The embryo-bearing females should be readily distinguishable from those of *S. hystrix* by the dorsal position of the embryos and their occurrence in fours. From *S. perspicax* the absence of the frontal eyes seems to be the only important distinction.

INTEGUMENTARY AND PEDAL GLANDS.

In *E. fustifera* the integumentary glands display a remarkable development. In each segment near its posterior limit they are arranged in a broad zone (Pl. **18**. fig. 49) which is much more strongly marked on the dorsal side than on the ventral. The secretion has a strong affinity for hæmatoxylin, and in many stained specimens the result is the appearance of a very characteristic pattern of transverse bands. The individual cells are irregular in shape and of small size for the most part; but in the middle ventrally, closely applied to the nerve-cord (see Pl. **18**. fig. 48 and fig. 50) are two or three of considerably larger size—these groups of larger cells having the appearance, in entire well-stained specimens, of dividing the nerve-cord into lengths corresponding to the segments.

In series with this zone of integumentary glands, but on a deeper level and projecting into the cœlom from the body-wall, there are on each side in the posterior part of each segment three larger rounded bodies (Pl. **18**. figs. 44 & 45, *i.gl.*; Pl. **18**. figs. 41 & 42), each made up of a group of unicellular glands with ducts opening on the surface about the lateral border of the segment behind the parapodia.

A feature of the glands last referred to which may be of physiological significance, is the development within them, or some of them, of excessively minute granules which pass out from the substance of the gland-cells into the cœlom as definite corpuscles (Pl. **17**. fig. 29).

The *pedal glands* are referred to by Malaquin (**22**), but only in the most general terms.

In *Exogone fustifera* the *pedal glands* are two pairs in each segment—a dorsal and a ventral (Pl. **18**. fig. 49, *v.p.g.*), each placed in close relation to the corresponding cirrus and partly contained within it. Of these the ventral, situated for the most part just internal to the ventral cirrus, but extending also into the interior of the latter, is of special interest since in the female it is the gland secreting the viscid substance by means of which the ova when discharged become attached to the parent.

In *E. verrugera* the integumentary glands are not condensed into transverse zones as in *E. fustifera*. They are fine convoluted tubules which are most abundant in the anterior region of the body. The pedal glands (Pl. **18**. fig. 36) are very similar to those of *E. fustifera*.

In *Sphærosyllis hystrix* the secretion of the integumentary glands forms a resistant layer in which small particles of grit become thickly embedded. This may be heaped over and around the papillæ in such a way as to give rise to the appearance of a system of comparatively large tubercles regularly distributed over the dorsal surface. This does not seem to be of the nature of a permanent layer since it varies greatly in thickness, and specimens are sometimes met with in which it is entirely absent. This point has already been referred to in the systematic part of this paper.

The ventral pedal glands (Pl. 17. fig. 30) are usually conspicuous in *S. hystrix*. In the female their secretion has, as in *Exogone*, the function of effecting the attachment of the eggs to the ventral surface.

In *Grubea kerguelensis* and *G. quadrioculata* the integumentary glands are diffused and inconspicuous.

"Capsules à bâtonnets" or rhabdite glands are not universal in the *Exogoneæ*. Among the species dealt with in this paper they occur in *Sphærosyllis hystrix*, *Grubea pusilloides*, and *G. kerguelensis*. In *Sphærosyllis hystrix* each is an oval sac situated on the dorsal and posterior side of the corresponding bundle of setæ and opening on the surface on the dorsal side of the parapodium: the slender rhabdites are often to be seen protruding through the external aperture. In *Grubea pusilloides*, as already described, there are two of these bodies in each of the remarkably modified dorsal cirri (Pl. 17. fig. 27). In *G. kerguelensis* they have almost exactly the same position as in *Sphærosyllis hystrix* and are found in all the segments from about the eighth backwards.

There is little doubt that where they occur these rhabdite glands represent a modification of the dorsal pedal glands of other members of the group.

In the absence of direct observation it may be conjectured that the main functions of the system of integumentary glands are protective: the viscid matter which they secrete becoming strengthened by the inclusion of foreign gritty particles may form a temporary investment as in *Exogone*, or may become closely adherent to the integument as in *Sphærosyllis*. With such a protective function is doubtless associated the entangling of animals seized upon as prey, permitting of their being effectively attacked by means of the proboscis.

The pedal glands, dorsal or ventral, as the case may be, assume in the female the special function of secreting the viscid matter by the agency of which the ova are caused to adhere firmly to the surface: since the same glands are equally developed in the male, it seems probable that in the latter sex they also have a special function—perhaps connected with fertilization.

The rhabdite glands, which in part replace pedal glands in some cases, doubtless have a specialised function in connection with the capture of prey and the warding off of enemies.

ALIMENTARY CANAL.

The pharynx in *Exogone fustifera* has the usual single tooth and the circlet of conical papillæ, which are eight or ten in number. In the living specimens in some cases droplets of clear liquid are to be detected exuding from apertures at the ends of the papillæ, and in connection with these are traceable fine ducts which are the ducts of the glands of the papillæ (pharyngeal glands). These (Pl. 17. fig. 1, *p.g.*) are about ten in number, in the shape of narrow cylinders, which extend backwards parallel with the pharynx, encircling it closely and becoming intimately attached to it behind. Each of these cylinders appears to be of the character of a group of unicellular glands each terminating orally in a slender duct.

These glands were observed by Claparède in various Syllids. Thus in his account of *Grubea limbata* (**2**. p. 208) he says :—"Tout autour (de la trompe) sont disposés des boyaux d'apparence glanduleuse." In his figure of *Pædophylax claviger* (pl. 13. fig. 2) the letter *g* points to a narrow body at the side of the pharynx which is referred to in the explanation as "glandes de la trompe." But this, though he seems to have mistaken it for them, has nothing to do with the "boyaux d'apparence glanduleuse," being situated within, not without, the wall of the pharynx, and probably is an indication of the body to be described presently under the designation of *anterior proventricular* glands. He overlooked altogether the occurrence of the structures in question in the larger Syllids, and only referred to them in connection with *Sphærosyllis*, *Pædophylax* (*Exogone*), and *Grubea*. The definite connection with the papillæ he appears not to have ascertained.

De St. Joseph (**31**), on the other hand, is very clear on both of these points. Malaquin (**22**. p. 196 *et seq.*) gives a very complete account of these pharyngeal glands and I have nothing to add to his observations. With regard to the functions which they may be supposed to discharge he remarks (p. 198), "Le contenu de ces glandes, se déversant par les papilles, a pour bout de les faire adhérer fortement à la proie, et, d'un autre côté, il a peut-être un rôle spécial dans l'absorption des aliments ; il se pourrait encore qu'il ait des propriétés toxiques destinées à neutraliser les mouvements de cette proie."

The pharynx has the usual thick cuticle with an epithelial layer of ill-defined cells which contain numerous yellowish granules. Posteriorly this layer swells out to form the *anterior proventricular gland* (Pl. **17**. fig. 1 : Pl. **17**. fig. 31 : Pl. **18**. figs. 37 & 38). This is a mass of irregular cells with, here and there, large vacuoles containing the secretion. From these a number of ducts, some wide, some narrow, pass backwards through the thick epithelium of the anterior part of the proventriculus, to open eventually into the lumen of the latter.

The structure just referred to seems to have escaped the notice of previous observers. The only reference to it which I have been able to find is the following statement of Malaquin's (**22**. p. 198) : "Dans la région postérieure de la trompe pharyngienne l'épithelium devient alvéolaire, et prend partout l'apparence d'un épithelium sécrétant, c'est qu'en effet, l'accroissement de la trompe et par conséquent de la chitine se fait par cette extrémité, d'avant en arrière."

This however, though describing the superficial appearance of the part, overlooks its real character and the special destination of the secretion.

The structure of the muscular organ which I have called the *gizzard*, but for which the name *proventriculus* used by Malaquin and others will be employed here, is similar in all essential respects to that of the corresponding organ in the Syllidæ. The proventriculus is a thick-walled cylinder, the lumen of which is reduced in the passive condition of the organ to the form of a vertical slit. Along the dorsal and ventral median lines opposite the ends of the slit run dorsal and ventral raphes along which the thickness of the musculature is greatly reduced. The greater part of the thickness of the wall is taken up by radiating muscular columns arranged in annular rows.

Malaquin (p. 213) states that the wall of the proventriculus consists of the following layers:—(1) peritoneal layer; (2) external circular muscles forming a thin layer; (3) radial muscle-columns separated by transverse diaphragms; (4) internal circular fibres; (5) the general columnar epithelium of the digestive tube; (6) the cuticle.

How far this is correct in relation to the *Syllidea*, *Eusyllidea*, and *Autolytidea* will not be discussed in this paper. In *Exogone fustifera* (and the other *Exogoneæ* which I have studied) there are no layers of circular muscle —the only circular fibres being those in the so-called diaphragms.

That the radial muscle-columns are in the Syllidæ striated muscle-fibres of a primitive type was pointed out by me (**16**) in 1886, and the subject was further elaborated in 1889 (**17**).

Malaquin (**22**), who was unacquainted with my second contribution to the subject, arrived independently at very similar results.

In *Exogone fustifera*, as in all the other *Exogoneæ* which I have examined, the muscle-columns (Pl. **18.** figs. 37, 39 & 40) are non-striated: they contain no doubly refracting substance and are devoid of transverse networks. In other respects they closely resemble the muscle-columns of *Syllidea*. They have a cortex of muscle-substance made up of fibrillæ, and a core of a granular protoplasmic material. Near the squarish outer end of the column is a nucleus usually single in the middle of the core; and in this region the protoplasm of each muscle-cell communicates with that of its neighbours in the same row by means of narrow processes.

In addition to these peculiar muscle-columns with their protoplasmic cores, the wall of the proventriculus also contains muscular fibres of the same character as those occurring in other parts of the body. These are arranged in narrow annular bands corresponding to the annular rows of muscle-columns. Each of these in *Exogone fustifera* (Pl. **18**. figs. 39 & 40) runs through the muscle-columns of the corresponding annular row close to their outer ends.

The muscle-columns of *E. fustifera* are divided by the circular muscles, usually unequally, the circular ring passing through at the level of the single nucleus of the column or deeper (according to the condition of contraction ?). The circular fibres have their own nuclei at intervals.

The internal epithelium and cuticle of the proventriculus, both very thin, present no special features of importance, except that the former is considerably thickened both in front where the ducts of the proventricular glands open, and behind in the neighbourhood of the entrance to the ventriculus.

The proventriculus is invested in a thin but resistant membrane which is doubtless derived partly or wholly from the splanchnic layer of cœlomic epithelium. It contains flattened nuclei at long intervals. In sections stained with iron-hæmatoxylin, it shows a fine irregular network of fibrils *.

The rest of the *Exogoneæ* examined by me resemble *Exogone fustifera* in the structure of the pharynx and proventriculus in all essential respects. The pharyngeal and proventricular glands are present in all. In all with one exception the rings of transverse fibres perforate the outer ends of the radial muscle-columns, dividing them either equally or unequally. The only exception is an undetermined species of *Grubea* in which the rings are arranged regularly *between* the annular rows of muscle-columns.

The ventriculus of *Exogone fustifera*, somewhat shorter than the proventriculus, is nearly as broad as the latter in front, but narrows behind towards the junction with the intestine. The wall of the organ contains radiating muscle-columns which are more widely spaced than those of the proventriculus and of simpler structure—solid and without protoplasmic core. Circular rings of fine muscular fibres run between the rows of columns close to the outer surface. The internal epithelium does not form a definite layer, but its cells lie irregularly among the muscle-columns. Here and there in the wall of the organ lies a unicellular gland. The ducts of these, the *posterior proventricular glands*, do not open into the lumen of the ventriculus but run forwards and pierce the epithelium to open into the posterior part of the proventriculus.

In *Sphærosyllis hystrix* the ventriculus has a definite epithelium. In *Grubea kerguelensis* and *G. quadrioculata* the ventriculus is so greatly reduced as to be practically obsolete. The other *Exogoneæ* studied resemble *Exogone fustifera* in the structure of this part of the alimentary system.

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* With regard to the relations between the circular and radial muscular fibres in the wall of the proventriculus, it is to be remarked that Malaquin takes a view which does not accord with the account above given. He regards the annular diaphragms, complete or incomplete, as always separating the rows of radial fibres, and he is thus led to the conclusion that such an arrangement as that occurring in *Exogone fustifera* (which is common also in the *Syllidea*) means that the radial muscle-columns of each row are arranged "back to back." But since it is exclusively with the *Syllidea* that he is dealing, it will be best to defer for the present entering further into this subject.

NEPHRIDIA.

Characteristic of the nephridial system in *Exogone fustifera* is the fact that in both sexes the nephridia of each pair unite completely towards the time of sexual maturity. In immature stages they are represented by pairs of narrow ciliated tubes of the usual character, with ciliated funnels. But in this and subsequent stages the walls of these organs are composed, not of few and comparatively large cells, as observed by Goodrich (**14**) in other Syllids, but of numerous small cells, as noticed by Claparède (**2**. p. 213, pl. 13. fig. 2 A) in the mature male of *Exogone clavigera*.

In the female in the earliest stage of sexual differentiation observed (Pl. **18**. fig. 48), each of the segments from the 12th backwards contains a pair of small ova, each enclosed in a sac with small-celled walls having a tubular outgrowth opening at the nephridiopore, The ciliated funnels at this stage appear to be entirely separate from the sacs. The derivation of the ova is unknown.

In specimens bearing embryos, in the segments on which embryos are situated, and in several in front and behind, nephridia are present having the following features. Each is a small oval sac with small-celled walls opening on the exterior through the nephridiopore, and of a short narrow canal leading from it to the adjacent nephridial funnel on the other side of the septum. The sac is contractile, the contractions being rhythmical though irregular, and the rhythm corresponding roughly with that of the contractions of the ventral vessel. The contractions have the effect of drawing the walls of the organ towards the attached external end. In sections it is seen that a transverse branch from the ventral blood-vessel ends blindly immediately in front of the nephridial sac, and it is probable that it is the contractions of this branch vessel that stimulate the contractions of the wall of the sac. At the stage now referred to, the sac does not contain an ovum —merely an irregular coagulum. But specimens without embryos were found as already stated having the nephridia in almost exactly the condition just described except that each sac contains a small ovum.

The ovum increases in size, distending the enclosing sac till its wall becomes reduced to a very thin membrane—the tubular efferent part being permanently retained with little alteration. As the two ova in each segment increase in size their enclosing sacs grow inwards towards one another. Eventually they meet in the middle line (Pl. **18**. fig. 49) and unite to form a single spacious sac enclosing the two ova and having on each side the original communication with the exterior. When the two sacs communicate, the two ova, instead of lying one on either side of the segment as at first (fig. 50), take up a new position one in front of the other, each extending transversely right across the cavity of the segment (fig. 51).

When the ova are discharged from the nephridial sacs each at once becomes attached by one end to the small area of the ventral surface (immediately internal to the base of the corresponding ventral cirrus) on which the ducts of the ventral pedal gland open. A mass of the secretion of the gland in question has collected within the gland : this must be pressed out, presumably as a result of the same contraction which leads to the discharge of the ova, and forms a viscid plug to which the ovum becomes fixed.

The position assigned by Viguier (**34**) in his description and figure (p. 89, pl. 4. fig. 19) to the discharged ova of *E. gemmifera* corresponds very closely to what I find to be the arrangement in *E. fustifera.* He is not right, however, in the statement that the point of attachment corresponds exactly to that of the opening of the "vésicule séminale" of the male : it is distinctly behind that point.

The sequence of events in the male is more complicated, and I have not been able to follow it out completely. The original simple, nearly straight, obliquely directed tube of the nephridium begins to become complicated in the manner described below. At this stage there is as yet no appearance of sperms. Later, when a mass of sperms has appeared, the pair of nephridia are represented by much looped tubes with walls of the chacteristic small cells. Subsequently the sexual segments have their cœlomic cavities (enlarged by the extreme attenuation of the intestine), with the extensions into the parapodia, filled with sperms—the nephridia in each segment now being represented by a single sac (Pl. **18**. fig. 45), apparently containing only a watery liquid with which it remains distended, and communicating with the exterior laterally by the nephridiopores. Sperms subsequently enter the nephridial sacs—presumably through the ciliated funnels. From the frequency with which this stage is met with it would appear to last for some time—the huge stock of accumulated sperms gradually being drawn into the nephridial sacs and becoming passed to the exterior.

When the male nephridia first appear they are developed as hollow ingrowths from the surface in the position of the nephridiopores. Each of these grows obliquely forwards and inwards, and becomes completed by passing through the mesentery and terminating in the ciliated funnel, which seems to be independently developed. The nephridium has now the character of a straight, or nearly straight, tube running obliquely from the nephridiopore on the ventral side of the segment a little in front of the parapodium to the nephrostome opening into the cavity of the segment next in front. Its wall, as in the case of the female, is composed of a single layer of small cells. The terminal part of the tube is dilated into a contractile sac as in the female.

The first change that takes place is the giving off of a branch from the sac not very far from its external opening (Pl. **18**. figs. 41 & 42). This grows backwards and becomes thrown into a loop. At the same time the original tube is drawn out into a loop which extends inwards and nearly meets its fellow of the opposite side in the middle line on the ventral side of the intestine.

Meanwhile the rudiments of the testes have appeared as masses of narrow tubes surrounding the nephridia closely and extending round the intestine towards the dorsal side. The origin of these testicular masses is difficult to trace. They are developed in close association with the nephridial tubes and are composed of cells at first very similar to the cells composing the walls of these tubes. But they are also from the first, or from an early stage, closely associated with the peritoneal lining of the sides of the intestine.

Before the testes are formed, or while they are still small, there is to be seen in the living animal in front of the nephridium a colourless thin-walled sac which contracts at intervals. This must correspond to the dilated end of the vascular cæcum described by Malaquin (p. 383) as forming the axis of the testis in the Syllidæ. It becomes hidden in *Exogone fustifera* when the testes develop, and I have been unable to trace it in sections. Its equivalent in the female is referred to above.

Later, when masses of sperms have been set free in the cœlom, the nephridia come to be represented by two relatively wide tubes (Pl. **18**. fig. 43), one on either side, still connected with the nephridiopore and provided with a ciliated nephrostome. Each becomes a sac with narrow lumen and thick wall composed of numerous small cells. The lumen of each sac increases in extent (Pl. **18**. fig. 44) and the cavities of each pair at length unite, though partly separated for a time by a septum which at last disappears, the wall of the unpaired sac (Pl. **18**. fig. 45) thus formed becoming at length thinned out till it assumes the character of a single layer of small cells.

The presence in *E. clavigera* of "vésicules séminales" which were in all probability formed each by the fusion in the middle line of a pair of nephridia was observed by Claparède (**2**. p. 212). He does not describe a corresponding fusion in the female.

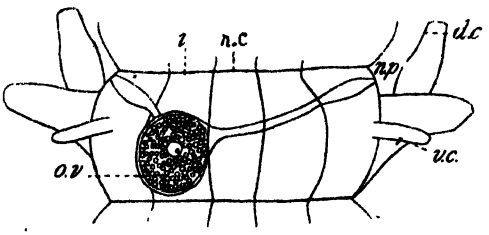
Viguier (**34**. p. 86) agrees with Claparède regarding the unpaired pouches of the male, but describes them as opening behind and not in front of the ventral cirri. In the ripe female he describes (p. 88) the two ova in each segment as increasing in size till they meet below the intestine, and one may pass in front of the other. From the results of compression he concludes that the apertures of egress are in front of the base of the parapodium.

De St. Joseph (**31**. p. 86) confirms Claparède's account as regards the male. With regard to the female he states :—"Une femelle de 25 segments a dans les 10e. à 23e. segments une masse vitelline grise sans noyau, entourée d'une membrane et commençant à se segmenter en deux; située sous le ventre entre l'intestin et la paroi du corps elle occupe presque toute la largeur du segment. Est-ce une poche renfermant deux œufs dont je n'ai pas vu le noyau et que commence a se séparer en deux ? Est-ce un œuf unique à son premier stade de segmentation ?"

Grubea pusilloides has the sexes united. The occurrence of this condition, so rare in the Polychæta, has been recorded by Du Plessis in another species of the same genus—*G. protandrica*. In *G. pusilloides* there is no protandry, so far as I have been able to observe—active sperms and maturing ova occurring together.

In a sexually mature specimen, before oviposition takes place, one large ovum is found in each of the 11th or 12th to the 16th or 17th segments (text-fig. 2). Each of these is lodged in a thin-walled sac formed by the union of the two nephridia of the segment and opening on the exterior by the two nephridiopores, situated just in front of the parapodia on the ventral side.

Text-fig. 2.



Development of ovum in *Grubea pusilloides*.
d.c., dorsal cirrus; *i.*, intestine; *n.c.*, ventral nerve-cord; *np.*, nephridiopore; *ov.*, ovum; *v.c.*, ventral cirrus.

The testes are developed as small irregular bodies in close connection with the nephridia in the 9th and 10th or 10th and 11th segments. There is no union between the nephridia of opposite sides. The sperms in the 9th segment collect in the posterior part of the segment and doubtless are taken up by the ciliated funnels, and passed to the exterior through the nephridia of the 10th segment. Sperms still remain active in specimens with three externally attached ova. In specimens with the full number (five) of external ova attached to the 10th to 15th segments sperms were still to be found in the male segments in front.

De St. Joseph states (**31.** p. 79) that in *G. pusilla* the female has two eggs attached to each segment from the 10th to the 26th.

In *Sphærosyllis hystrix* in the male the early development of the nephridia and testes takes place very much as in *Exogone fustifera*. Later the inner portions of the testes unite in the middle line. In mature males with the cœlom full of sperms, the two nephridia of each segment, which remain quite separate from one another, have assumed the form of coiled thick-walled tubes with degenerate epithelium. In the female the two ova developed in each segment (Pl. **18.** fig. 16) are in early stages of growth, each enclosed in a sac with a wall composed of a single layer of cells and apparently corresponding to the nephridial sac of other *Exogoneæ*. But in specimens with full-grown ova this investment has completely lost its cellular character and has quite the appearance of a cuticle.

In young females of *Grubea kerguelensis* there are four small ova on each side in each segment. Two of these occupy a position in the segment corresponding to that occupied at first by the only two in *Exogone fustifera*, lying nearly transversely—the other two are situated laterally. Each of the transverse ova is situated in a thin-walled sac (nephridium) opening in the usual position, and there can be little doubt that the investment of each of the other ova is a prolongation of this sac.

So far as the material at command goes, *Grubea quadrioculata* corresponds closely in the female reproductive apparatus to *G. kerguelensis*.

EMBRYOLOGY.

For our earliest information on the development of the *Exogoneæ* we are indebted to Œrsted (**25**), who gave a brief account of some of the stages as seen in his *Exogone naudina*.

Viguier (**34**) notes some points in the development of *Exogone gemmifera*. The segmentation stages figured do not, the author acknowledges, throw any light on the mode of formation of the germinal layers, but he thinks it probable that there is an invagination the orifice of which becomes the anus. The buccal invagination appears somewhat late. When the larva becomes detached it possesses five setigerous segments.

De Saint Joseph (**31**) describes various stages in the later development of *E. clavigera* and makes an interesting observation on the difference between the development of *Grubea clavata* and *G. pusilla* which will be referred to later.

The only other recorded observations on the embryology of the *Exogoneæ* are those of Pierantoni (**28**). This author made a noteworthy contribution to our knowledge of the remarkable phenomenon of epigamy; but the objects which he aimed at in his research did not include a complete study of the embryology. His results as regards the embryology of *Sphærosyllis hystrix* may be summarised as follows :—

The ovum divides into two blastomeres of which one divides rapidly into two, four, and eight, while the other divides much more slowly. From the successive divisions of the former blastomere there result a great number of micromeres (ectoderm) and from those of the other a very small number of macromeres (endoderm) which ultimately become enclosed within the micromeres ; the former at this stage are only eight in number.

Both micromeres and macromeres increase in number, but, as regards the latter, after the stage of eight cells it is no longer possible to distinguish the individual elements, the whole appearing as a mass of red yolk-matter.

In *Exogone fustifera* the ova when discharged are fixed to the ventral surface just internal to the ventral cirri—the attachment being effected, as already stated, by means of the secretion of the ventral pedal glands. A pair is attached to each segment from the 11th or 12th as far back sometimes as the 43rd or 44th.

The earliest stages of development closely resemble corresponding stages in the Polychæta in general. Complete segmentation results in division into four cells from which the four primary micromeres are derived by further division.

But I have not attempted to follow out the details of the cell-lineage—a task which, in view of the minuteness of the ova and the small number of stages available, would be one of peculiar difficulty. I can only record the increase in the number of the micromeres until, while the four macromeres still remain unaltered, they come to form a cap of small cells on one side of the embryo.

I have not succeeded in observing a stage when the micromeres have completely enclosed the mass of macromeres. Or perhaps it would be more correct to say, that when such an investment has taken place, some differentiation has already been effected. Since no stage intermediate between those represented respectively by figs. 52 and 53 of Pl. **18** has been observed, it would appear probable that a process of differentiation goes on *pari passu* with the extension of the investing layer of micromeres. This differentiation results in the formation of two centres or areas of development—the dorsally situated *dorsal plate* (Pl. **18**. figs. 54–57, *d.pl.*) and the ventral *stomodæal tract* (Pl. **18**. figs. 54–57 and figs. 58 & 59, *st.*). The former is early distinguishable into anterior and posterior lobes, and consists at first of only a single layer of cells. The latter at the outset appears as a small rounded group of cells irregular in shape and arrangement in the middle of the surface of the embryo destined to be ventral, and about midway between the two poles.

The dorsal plate sends off posteriorly a pair of outgrowths which eventually meet and unite at the posterior end of the body. These outgrowths, the *germinal bands* (*g.b.*), are separated from one another both on the dorsal and on the ventral surface by areas composed of ectoderm (enclosing the mass of yolk). Sections of embryos at this stage (Pl. **18**. fig. 59) show that each germinal band is composed of two layers, a superficial with smaller nuclei —the ectoderm,—and a deeper with larger nuclei—the mesoderm.

The stomodæal area has in the meantime been undergoing differentiation. A depression has appeared on the surface which deepens and penetrates into the mass of cells as a sharply-defined cylindrical pit. Latterly the stomodæal rudiment sends out a string of cells which extend to the angles of the dorsal plate, or more exactly, of the posterior lobe of the latter. The destiny of those clearly defined bands passing out right and left of the stomodæum and joining the apical plate dorsally, has not been followed. They very soon lose their distinctness.

Each germinal band now undergoes a process of transverse segmentation (Pl. **18**. figs. 62–65). In the region at the posterior end in which the two have become united they give rise to the rudiment of the pygidial segment.

In front each germinal band divides into five segments, the first smaller than the rest, which are subequal. Sections show that, like the germinal bands, each segment is composed of two layers, a superficial, ectodermal, and a deeper, mesodermal (Pl. **18.** fig. 63).

The area between the two rows of somites continues to be covered dorsally by a very thin ectoderm. Ventrally, on the other hand, at the stage when segmentation has been completed, is a thicker layer of closely-set small cells divided along the mid-ventral line by a raphe or suture (Pl. **18.** figs. 62 & 64). This is obviously the rudiment of the ventral nerve-cord. Whether it is formed from the thin ectodermal layer originally present in this position or by lateral ingrowth from the two germinal bands has not been actually determined. But the latter mode of origin, especially in view of the presence of the median raphe, is by far the more probable. At this stage the rudiment of the nerve-cord presents no trace of segmentation.

The dorsal plate has thickened materially and extended over the anterior (free) end of the embryo (Pl. **18.** figs. 58–64). The stomodæum has extended and assumed a rounded form. Posteriorly it gives off an extension—the rudiment of the proventriculus—the original stomodæum becoming the pharynx. The epithelium of the former has formed around it a simple layer of cells which tend to elongate radially, these are destined to form the radial muscular fibres of the proventriculus. External to this and closely applied to it are flattened cells which may form a continuous layer.

The next change of importance is the appearance of the first rudiments of the tentacles (figs. 64 & 65). The free or head end of the embryo had already developed a solid thickening—the rudiment of the closely united palpi. On the dorsal side of this appear two, to which a third (median) is soon added, small knobs—the beginnings of the cephalic tentacles. About the same time appear the rudiments of the anal cirri. The peristomial tentacles do not appear till considerably later. At this stage there are six pairs of mesodermal somites, the members of each pair widely separated from one another.

When the rudiments of the parapodia first appear as slight lateral projections they are developed from the somites.

It appears to be clear that the cœlom cannot be formed in the same way as in Polychæta in general. At the stage when rudimentary setæ first make their appearance in the parapodia the stomodæum ends behind in a mass of tissue in which the large yolk-granules are embedded. This tissue, derived as has been seen, from the macromeres, no longer retains the character of distinct cells, but has all the appearance of such a syncytium as that presented by the enteric or endodermal mass of the "Acœlous" Turbellaria or certain of the Rhabdocœles. In these the food is digested in larger or smaller vacuoles in the syncytium. In the embyro of *Exogone fustifera* the yolk-granules, which take the place of food, are similarly contained in vacuoles in the syncytium. This syncytial tissue with its contained yolk-granules completely fills the interior of the body and is continuous externally with the body-wall; there is at this stage neither mesenteron nor cœlom.

The changes which result in the formation of these—the mesenteron and cœlom—take place in the last stages before the young worms become free. In such a late larva (fig. 66) it is found that the syncytium has undergone a profound modification. A cylindrical space has been formed through the mass of yolk-containing tissue along the axis of the larva towards the dorsal side. This becomes continuous with the lumen of the stomodæum in front and that of the proctodæum behind.

The most advanced larvæ observed have five setigerous segments.

Exogone verrugera and *E. heterosetosa* have the ova arranged exactly as *E. fustifera*, in pairs from the 10th or 11th segment backwards. The stages in the development are essentially the same, and the oldest fixed larvæ have each five setigerous segments.

In *Grubea quadrioculata* the eggs, which are ·12 mm. in long diameter, are attached dorsally to the surface between the dorsal cirrus and the parapodium—a pair on each segment from the 13th or 14th to about the 30th. A peculiar feature of this form is that there are invariably two, sometimes even three, more or less widely separated stages occurring together. The arrangement of these is various, but usually all the eggs of the same stage are grouped together; sometimes, however, there is more or less mixing. The means of attachment are not very obvious; but from the position occupied it seems highly probable that the secretion of the dorsal pedal glands performs this function.

The early stages are not in any noteworthy manner different from the corresponding stages of *E. fustifera*. The early stages of segmentation were observed and the formation of the ectodermal cap. A stage was obtained in which the ectoderm as a thin, irregular layer encloses an endoderm of about a dozen large clearly-defined cells.

The chief peculiarities which appear in later stages are associated with the fact that the embryo, instead of growing straight out, the egg-membrane either disappearing or becoming converted into the cuticle, is developed flexed dorsally within the egg-membrane (Pl. **18**. fig. 68), from which it only escapes when the tentacles and the parapodia of the primary segments have appeared.

As in *Exogone*, the development of the embryo proceeds from two separate centres—the dorsal plate and the ventral stomodæal rudiment. The former early becomes divided into two by a deep constriction, the anterior part forming the *head plate* and the posterior the *body plate*. From the latter the germinal bands (Pl. **18**. fig. 67) grow more directly downwards (ventral), in accordance with the destined flexure. The head plate extends earlier over the anterior end of the egg than in *Exogone*. The stomodæal rudiment appears as a plug of cells which becomes extended transversely and is connected with the dorsal plate by a pair of narrow cords. The plug becomes invaginated by a narrow transverse slit which later becomes a deep rounded pit.

In *G. kerguelensis* the eggs, which are only half the size of those of *G. quadrioculata* (·06 in long diameter), are attached dorsally, typically four on each segment from the 7th to the 17th. The course of the development is essentially the same as in *G. quadrioculata*.

The peculiar mode of development of *Grubea quadrioculata* and *G. kerguelensis*, flexed within the egg, appears to be shared by at least one other member of the genus, viz. *G. clavata*. In comparing the development of that species with that of *G. pusilla*, De St. Joseph remarks (p. 80):—"Chez la première, les embryons se développent dans l'œuf sur le dos de la mère, dont ils se séparent dès qu'ils sont murs en sortant de l'œuf; chez la deuxième ils se développent sous le ventre de la mère et y restent fixés après qu'ils sont sortis de l'œuf" (p. 80).

In *G. pusilloides* there are few, not more than five, eggs attached loosely to the ventral surface, one on each of the segments from the 11th to the 16th. The mode of attachment has not been observed. The embryo is straight; the stages of development observed resemble the corresponding stages of *Exogone fustifera* rather than that of the other species of *Grubea*.

In *Sphærosyllis hystrix* the eggs are attached to the ventral surface of the parent by means of the secretion of the ventral pedal glands (Pl. 17. fig. 30). Sometimes this secretion, or that of the neighbouring integumentary glands, is poured out so abundantly that it forms an investment for each ovum, and this may have embedded in it numerous minute gritty particles which render it very opaque; frequently this investment is not present, and the egg appears quite clear, being enclosed only in the thin vitelline membrane.

Regarding the mode of attachment of the eggs in this form, Pierantoni states (p. 243): "Lo strato di sostanza mucosa que involge l'uovo è sottilissimo, salvo nel punto di attacco ove è più spesso e di consistenza quasi gelatinosa, e prende l'aspetto di sottili cordoncini trasparenti che corrono dall' uovo alla parete esterna del corpo dell' animale, intorno al punto di immediato contatto."

In addition to the delicate filaments referred to in the above quotation, certain other structures become visible in the supporting plug or stalk, when sections of it are stained with eosin (Pl. 18. fig. 47). These are a series of rod-like bodies arranged quite regularly parallel with one another and at right angles to the surface of the worm. These must be formed from the eosinophilous granules which, as already pointed out in the part of this paper dealing with the integumentary glands, forms a part of the secretion of the ventral pedal glands in this species.

My preparations quite definitely contradict Pierantoni's account of the early stages in one point. One set consists of a 4-celled stage in which the cells are quite equal and symmetrical with the nuclei approximated towards the animal pole evidently in preparation for the formation of the first four micromeres, as in the other *Exogoneæ* and in the Polychæta in general. Later stages observed also correspond quite closely with those of *Exogone*.

Summary.

The following are the most important of the results embodied in this paper :—

1. Descriptions and determinations of Australian species of *Exogoneæ*.

2. Demonstration of the rôle of the pedal glands in producing the secretion by means of which the ova are attached after extrusion.

3. Description of the proventriculus with its non-striated muscle-columns, and of hitherto undescribed glands—the proventricular glands—the ducts of which open into it.

4. The following out of the changes undergone in *Exogone* by the nephridia in both sexes associated with the development of the sexual elements.

5. The hermaphrodite condition in *Grubea pusilloides*.

6. Description of stages of the development not previously investigated.

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* Only known to me through the account given by Potts (29).

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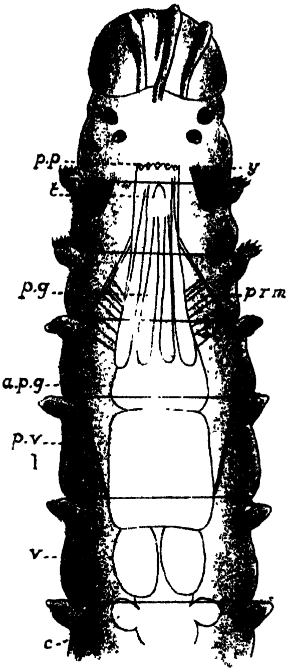
Haswell



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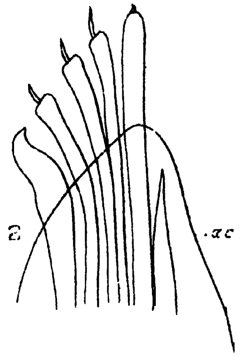

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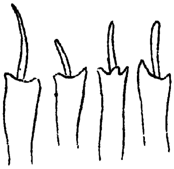

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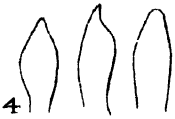

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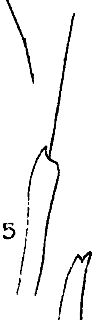

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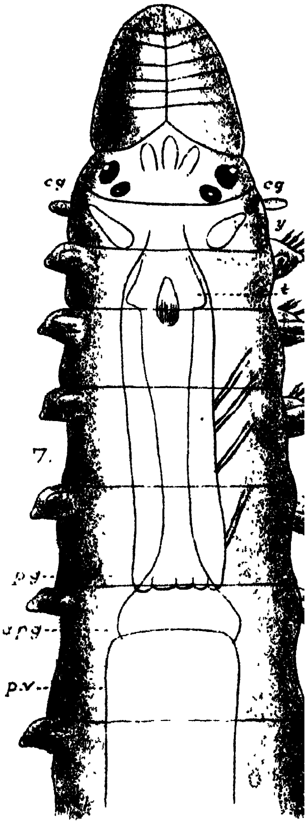

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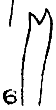

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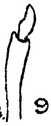

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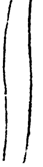

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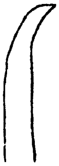

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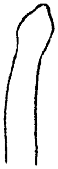

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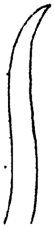

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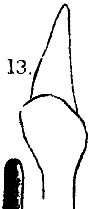

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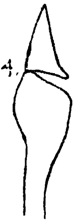

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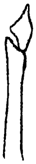

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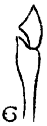

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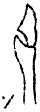

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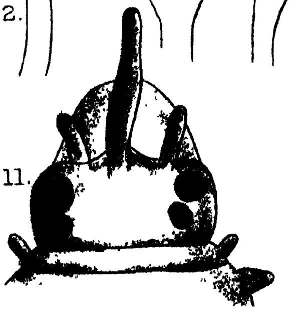

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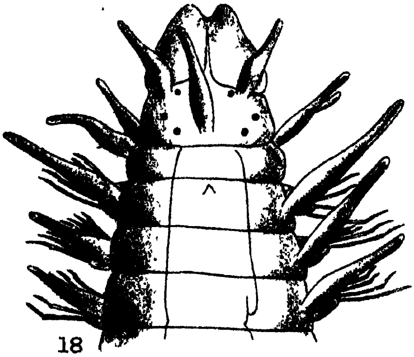

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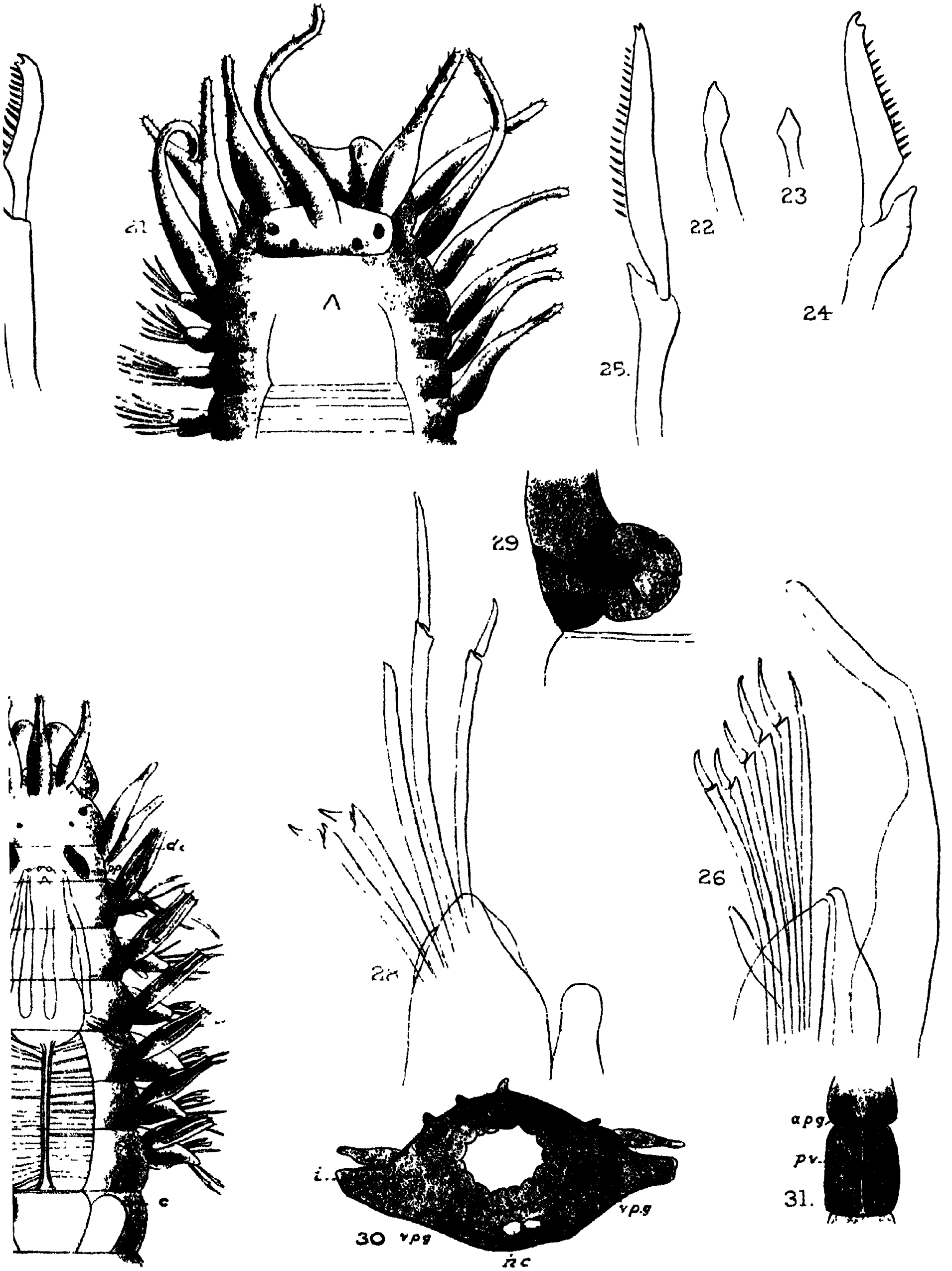
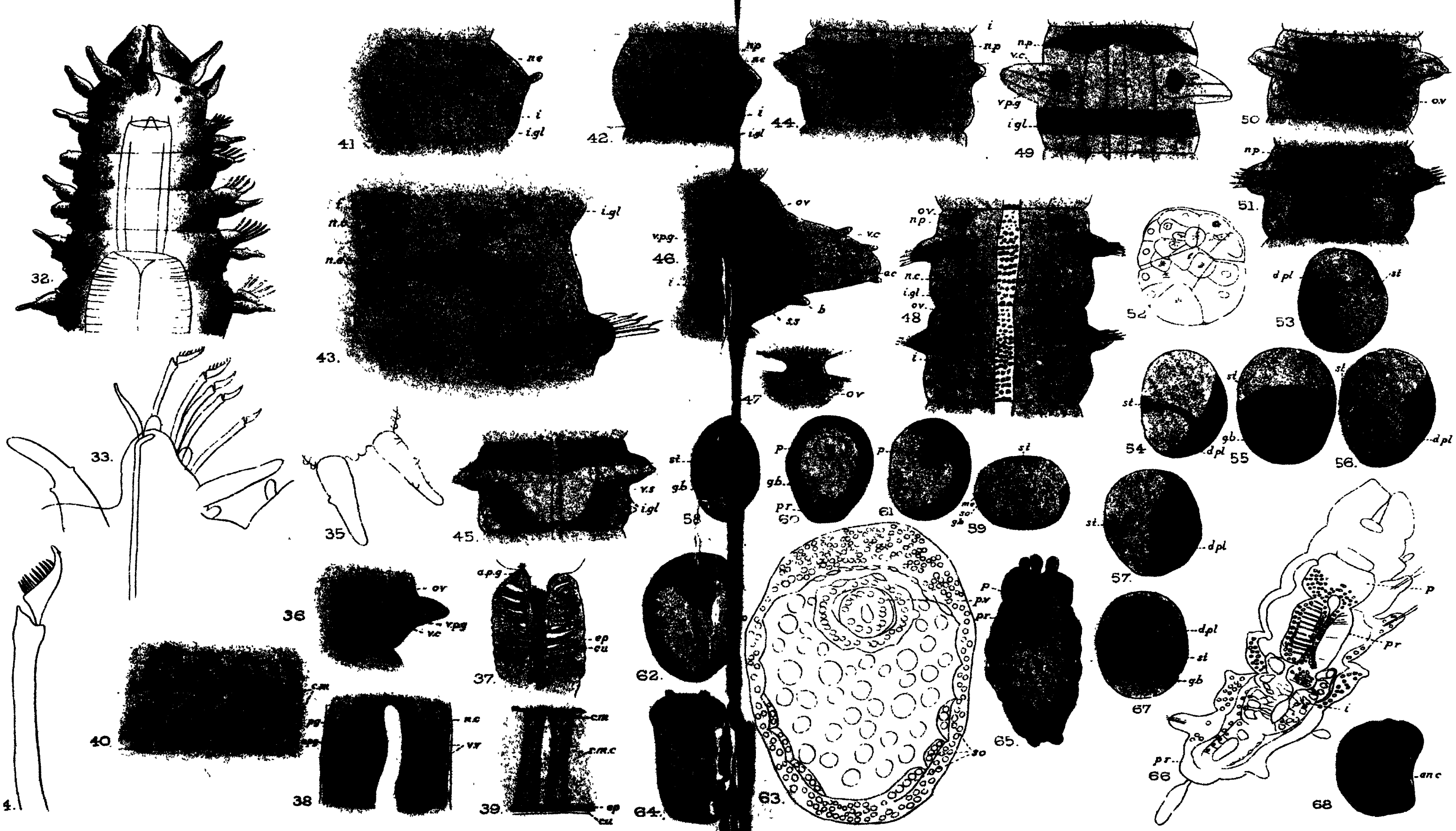


C Hodges & Son imp

EXOGONEAE.



G.L. Birbel. lith.

AUSTRALIAN KOGONEAE

C Hodges & Son imp

EXPLANATION OF THE PLATES.

LETTERING.

ac.	aciculum.
an.c.	anal cirrus.
a.p.g.	anterior pro-ventricular glands.
b.	rhabdite glands.
c.	cæca.
c.f.	ciliated funnel.
c.g.	ciliated groove.
c.m.	circular muscles.
cu.	cuticle.
d.c.	dorsal cirri.
d.p.g.	dorsal pedal gland.
d.pl.	dorsal plate of embryo.
ep.	epithelium.
f.	funnel.
g.b.	germinal bands.
i.	intestine.
i.gl.	integumentary glands.
n.c.	ventral nerve-cord.
ne.	nephridium.
n.p.	nephridiopore.
ov.	ovum.
p.	pharynx.
p.g.	pharyngeal glands.
p.p.	pharyngeal papillæ.
p.r.	proctodæum.
pr.m.	protractor muscles of proboscis.
p.v.	proventriculus.
r.m.c.	radial muscle-columns.
so.	somites.
s.s.	setigerous sac.
st.	stomodæum.
t.	pharyngeal tooth.
v.c.	ventral cirrus.
v.p.g.	ventral pedal gland.
v.v.	ventral vessel.
y.	yellow gland.

All the figures from drawings by the author.

PLATE 17.

Fig. 1. *Exogone fustifera.* Anterior region, dorsal view, magnified, with outline of alimentary canal, etc.

2. *E. fustifera.* Dorsal view of parapodium. × 1040.

3. *E. fustifera.* Samples of compound setæ.

4. *E. fustifera.* Most dorsal seta, ordinary form.

5. *E. fustifera.* Most dorsal seta, form with appendage.

6. *E. fustifera.* Most ventral seta, strongly bidentate form. × 1040.

7. *E. verrugera.* Anterior region.

8. *E. verrugera.* Second compound seta. × 1040.

9. *E. verrugera.* Most ventral, simple seta. × 1040.

Figs. 10*a* & 10*b*. *E. verrugera.* End of aciculum. × 1040.

Fig. 11. *E. heterosetosa.* Head end. × 440.

Fig. 12. *E. heterosetosa.* Most dorsal, simple seta. × 1040.

Figs. 13 & 14. *E. heterosetosa.* First (most dorsal) compound seta, two varieties.

Figs. 15, 16, 17. *E. heterosetosa.* Ordinary compound seta.

Fig. 18. *Grubea kerguelensis.* Anterior end. × 440.

19. *G. kerguelensis.* Most dorsal, simple seta. × 1040.

20. *G. kerguelensis.* Compound seta.

21. *G. quadrioculata.* Anterior region. × 440.

Figs. 22 & 23. *G. quadrioculata.* End of aciculum.

Figs. 24 & 25. *G. quadrioculata.* Compound setæ.

Fig. 26. *G. quadrioculata.* Parapodium and cirri, ventral view. × 440. All the compound setæ are not represented.

27. *G. pusilloides.* Dorsal view of anterior region. × 300. Only one of the two rhabdite glands in each parapodium is represented.

28. *G. pusilloides.* Parapodium from the dorsal side. × 1040.

29. Section of one of the groups of granule-producing glands of *E. fustifera.* × 800.

Fig. 30. *Sphærosyllis hystrix*, ♀. Outlines of transverse section showing the position of the ventral pedal glands. × 300.

31. *Exogone fustifera.* Outlines of proventriculus from stained and cleared specimen, showing the anterior proventricular glands and their ducts. × 440.

Plate 18.

Fig. 32. *Sphærosyllis hystrix.* Anterior region from the dorsal side. × 240. Setæ only represented on one side.

33. *S. hystrix.* Parapodium and cirri. × 440.

34. *S. hystrix.* First (most dorsal) compound seta. × 1040.

35. *S. hystrix.* Anal cirri.

36. *Exogone verrugera.* Ventral view of a portion of a stained and cleared specimen of a female with early ova, to show the ventral pedal gland with its mass of secretion.

37. *E. fustifera.* Horizontal section of proventriculus, showing ducts of anterior proventricular glands.

38. *E. fustifera.* Sagittal section in the region of the junction of the pharynx and proventriculus, showing anterior proventricular glands and ducts.

39. *E. fustifera.* Muscle-columns as seen in horizontal sections of the lateral wall of the proventriculus.

40. *E. fustifera.* Transverse section through outer ends of muscle-columns as seen in horizontal series.

Figs. 41 & 42. *E. fustifera.* Corresponding parts of two successive longitudinal (horizontal) sections of a male specimen showing a nephridium at the point where it opens on the exterior, with the bifurcation of the main duct to form two loops. × 440.

Fig. 43. *E. fustifera.* General view of nephridium *plus* testis at an earlier stage than that represented in Figs. 41 and 42. From a stained and cleared specimen. × 1040.

44. *E. fustifera.* Segment of a male specimen in which the nephridia *plus* testes are far advanced in development, but have not yet begun to unite mesially. As in the following figure, the setæ are merely indicated.

45. *E. fustifera.* Semi-diagrammatic view of a segment of a ripe male with the median vesicle surrounded by a mass of sperms.

46. *Sphærosyllis hystrix.* Ventral view of left portion of a segment with young ovum enclosed in its follicle (nephridium) and the ventral pedal gland with the mass of secretion by means of which the egg becomes attached after it has been discharged.

47. *S. hystrix.* From a section passing through the point of attachment of an embryo (*ov.*) to the ventral surface with the plug of secretion by means of which the attachment is maintained. × 440.

All the figures refer to *Exogone fustifera.*

Fig. 48. Ventral view of two segments of female with early ova. From stained and cleared specimen. × 440.

49. View of a segment of a female in which the two ovisacs (nephridia) have become fused together across the middle line. Shows also the positions of the ventral pedal glands and the zone of integumentary glands. × 440.

50. Segment of a female with the two ova fully grown lying side by side in the common follicle or nephridial sac. × 440.

51. Segment of a female with the two ova lying one in front of the other. From stained and cleared specimen. × 440.

Fig. 52. Stage in the epiboly in which the four original cells (macromeres) still maintain their individuality: the nuclei of these are marked with small crosses. × 440.

53. Lateral view of embryo with dorsal plate and stomodæal rudiment, before the appearance of the germinal bands.

54. Lateral view of an embryo at a somewhat later stage than that represented in fig. 53, with the pair of narrow bands running from the stomodæal rudiment to the apical plate.

55. Ventral view of an embryo of about the same stage as that represented in fig. 54, but with the stomodæal rudiment more extended laterally and the germinal bands beginning to appear.

56. Lateral view of a similar stage to that represented in fig. 55.

57. Lateral view of a somewhat more advanced stage with the dorsal plate extending forwards nearly to the free end.

All the figures, except 67 and 68, refer to *Exogone fustifera.*

Fig. 58. Ventral view of an embryo at the stage in which the germinal bands meet posteriorly: the stomodæal rudiment, transversely elongated and connected with the dorsal shield by a pair of narrow strands, is not yet definitely invaginated. × 440.

59. Transverse section of embryo at about the stage represented in fig. 58. × 440. *so.* here points to the germinal band.

60. Ventral view of an embryo with the stomodæal invagination completed, the germinal bands well established, meeting behind to surround a proctodæal area. × 440.

61. Lateral view of the embryo represented in fig. 60. × 440.

62. Ventral view of embryo in which the germinal bands have become segmented and the stomodæum, destined to become the pharynx, has given off an offset which will develop into the proventriculus. × 440.

63. Horizontal section of stage similar to that represented in fig. 62. × 1000.

64. Stage of the first appearance of the tentacles. × 440.

65. Stage with well developed prostomial tentacles and without rudiments of the parapodia. × 440.

66. Horizontal section of advanced embryo with five segments and parapodia with setæ. × 440.

67. *Grubea kerguelensis.* Stained and cleared early embryo, viewed somewhat obliquely from the ventral side. The dorsal plate deeply constricted into head plate and body plate, and the latter giving off ventrally the germinal bands. × 440.

68. *Grubea quadrioculata.* Late embryo stained and cleared: outline, to show the ventral curvature. × 300.

SPOLIA RUNIANA.—IV. Notes on the Abundance of some Common Marine Animals and a preliminary Quantitative Survey of their Occurrence.

By W. A. HERDMAN, D.Sc., LL.D., For.Sec.R.S., F.L.S., Professor of Oceanography in the University of Liverpool.

(With 8 Text-figures.)

[Read 11th December, 1919.]

FOR many years I have taken any opportunities that offered, both on dredging expeditions in the 'Runa' and also when tramping the sea-shores of various parts of the world, of making observations on the abundance and mode of occurrence of the common marine animals and plants. Two years ago I brought before the Society some statistics and conclusions as to the occurrence and distribution of the commoner planktonic organisms, Diatoms and Copepoda, throughout the year in the Irish Sea [*], with the object of showing that the supply of such food-matters to our plankton-eating fishes depends upon a surprisingly small number of species which are present in enormous abundance. Some half-dozen kinds of Diatoms and about the same number of Copepoda are the all-important organisms upon which our fate depends so far as concerns our food from the sea. I desire now to place on record some notes as to the occurrence of a few of the commoner fixed or sedentary bottom-living animals of the sea-shore or shallow-water—animals which are also, like the plankton, of great practical importance in nature as the chief food of some of our most valuable fishes.

Our knowledge of the number of animals living in different regions of the sea is for the most part relative only. We know that one haul of the dredge is larger than another, or that one locality seems richer than another, but we have very little information as to the actual numbers of any kind of animal per square foot or per acre in the sea [†]. Some years ago Hensen attempted to estimate the number of food-fishes in the North Sea from the number of their eggs caught in a comparatively small series of hauls of the tow-net, but the data were probably quite insufficient and the conclusions may be erroneous. It is an interesting speculation to which we cannot attach any economic importance.

All biologists must agree that to determine even approximately the number of individuals of any particular species living in a known area is a contribution to knowledge which may be of great economic value in the case of the edible fishes; but it may be doubted whether Hensen's methods, even with greatly increased data, will ever give us the required information. Petersen's method, of setting free marked plaice and then assuming that the proportion of these re-caught is to the total number marked as the fishermen's catch in the same district is to the total population, will only hold good in circumscribed areas where there is practically no migration and where the fish are fairly evenly distributed.

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[*] "Spolia Runiana—III.," Journ. Linn. Soc., Zool. xxxiv. p. 95 (1918).

[†] Professor McIntosh, in his book 'The Resources of the Sea' (1899), gives a vivid picture of the abundance of life of all kinds in the sea, but does not venture upon any numerical estimates.

It is difficult to imagine any method which will enable us to estimate any such case as, say, the number of plaice in the North Sea*, where the individuals are so far beyond our direct observation and are liable to change their positions at any moment. But a beginning can be made on more accessible ground with more sedentary animals, and that is what I have been attempting to do. Dr. C. G. Joh. Petersen, of the Danish Biological Station, has for some years been pursuing the subject in a series of interesting Reports on the "Evaluation of the Sea" †. He uses a bottom-sampler or grab, which can be lowered down open and then closed on the bottom so as to bring up a sample square foot or square metre (or in deep water one-tenth of a square metre) of the sand or mud and its inhabitants. With this apparatus, modified in size and weight for different depths and bottoms, Petersen and his fellow-workers have made a very thorough examination of the Danish waters, and especially of the Kattegat and the Limfjord, have described a series of "animal communities" characteristic of different zones and regions of shallow water, and have arrived at certain numerical results as to the quantity of animals in the Kattegat expressed in tons—such as 5000 tons of plaice requiring as food 50,000 tons of "useful animals" (Mollusca and Polychæt worms), and 25,000 tons of starfish using up 200,000 tons of useful animals which might otherwise serve as food for fishes; and the dependence of all these animals directly or indirectly upon the great beds of Zostera, which make up 24,000,000 tons in the Kattegat. Such estimates are obviously of great biological interest, and, even if only rough approximations, are a valuable contribution to our understanding of the metabolism of the sea and of the possibility of increasing the yield of local fisheries.

But on studying these Danish results in the light of what we know of our own marine fauna, although none of our seas have been examined in the same detail by the bottom-sampler method, it seems probable that the animal communities as defined by Petersen are not applicable on our coasts, and that the estimates of relative and absolute abundance may be very different in different seas under different conditions. The work will have to be done in each great area, such as the North Sea, the English Channel, and the Irish Sea, independently. This is a necessary investigation, both biological and physical, which lies before the oceanographers of the future, upon the results of which a rational conservation and exploitation of our national sea-fisheries may depend.

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* Heincke, however, has attempted to estimate the adult plaice at 1500 millions, of which 500 millions are caught annually.

† See 'Reports of the Danish Biological Station,' and especially the Report for 1918, "The Sea Bottom and its production of Fish Food." Professors L. Joubin and Guérin-Ganivet have published a series of papers, entitled "Gisements de Mollusques comestibles des Côtes de France" (Bull. Mus. Ocean. Monaco, from 1906 onwards), surveying the shell-fish beds and fisheries, but giving no estimates of numbers present.

My own contributions to the subject so far deal only with the shore and shallow-water animals of the littoral and the top of the Laminarian zone, and I shall give here merely a few examples from different groups of animals and plants, and from different localities, mainly to demonstrate the enormous abundance of some of the commonest, and therefore the most important, of the animals and plants on what are sometimes called our "barren" sea-shores. I shall first take the cases of a worm, a crustacean, a mollusc, and an ascidian—all forms that are free-swimming when young but fixed in the adult condition, and all of value as food of marketable fishes.

SABELLARIA.

The gregarious Polychæt Annelid *Sabellaria alveolata* is present in great abundance on many parts of the coast of North-West Europe, generally on

FIG. 1.—*Sabellaria alveolata*, from Hilbre Id., nat. size.

shores where stones or patches of rock crop out in proximity to sand and where strong tidal currents disturb the sand and carry the suspended grains along in quantity. The worms stick the sand-grains together to form the tubes in which they live and which adhere to one another so as to build up solid masses of a porous, crisp and brittle material, which crumbles to a certain extent when walked upon, but which is constantly being renewed and has its injuries repaired by the living worms within, and must, therefore, have a very considerable effect in some places in protecting the rocks or shore generally from the erosive action of the sea. On Hilbre Island, in the Estuary of the Dee, for example, *Sabellaria* covers the soft red triassic sandstones with encrusting sheets, rising in places to form massive hummocks and outstanding reefs many yards in extent; and the same reef-like formations are to be seen on a still larger scale on the coast of Normandy, near Granville, Mount St. Michel Bay, and elsewhere.

I have measured and counted numbers of samples of these *Sabellaria* tubes, and find that the diameter of the mouth of the tube is generally between an eighth and a tenth of an inch. Of course, there are also smaller ones, those of the young worms in the mass, and a few larger, but a fair average size is one-tenth of an inch. A photograph (fig. 1) of such a mass of *Sabellaria* tubes shows that in a surface of about three square inches there are from 65 to 75 mouths of tubes. Taking 65, a square foot would have 3120 and a square yard some 28,080 of the worms. Hence, forty square yards would contain over a million. Now, there are very many square yards of *Sabellaria* on the shore at such a locality as Hilbre Island, containing, therefore, millions of worms, each from one to two inches in length, and such Polychæt worms are a favourite food of flat-fish like the plaice and sole, and can be easily obtained by crunching up the brittle sand-tubes. Roughly, about half of a mass of *Sabellaria* tubes consists of sand and the rest is formed of the nutritious worms.

Sabellaria is not found on the shore only, but extends beyond low-water mark for some distance. I have dredged lumps of it from depths of about 10 fathoms, off the Lancashire coast, near Fleetwood, and in some places it it so abundant at the bottom, and comes up so frequently in the fishermen's nets, that it is familiar to them, and is known by the local name of "knarrs." That flat-fish are present on this trawling ground is probably due in part to the abundance of the *Sabellaria* masses on the bottom.

BALANUS.

The common rock-barnacle *Balanus balanoides* is probably the most abundant fixed animal on the rocky shores of North-West Europe. On many sea-cliffs the barnacles form a layer covering practically every inch of rock between the tide-marks. Bradda Head at Port Erin is a good example, and at low tide, when seen from a distance, it looks as if a horizontal band of whitewash had been painted along the base of the cliff. When examined in detail, it is found that the barnacles—young and old—form a continuous layer, roughening the whole surface of the rock and leaving scarcely any spots of stone exposed. In fact, the individual barnacles in many cases have not room to grow to the normal size. They are overcrowded, and by mutual pressure are caused to assume vertically elongated prismatic forms, like columnar basalt. A quarter of an inch square is an average size for an adult

Balanus, and there are 2304 square quarter inches in a square foot. But on one square foot of rock at Fleshwick Bay, near Port Erin, 2940 barnacles were counted (fig. 2).

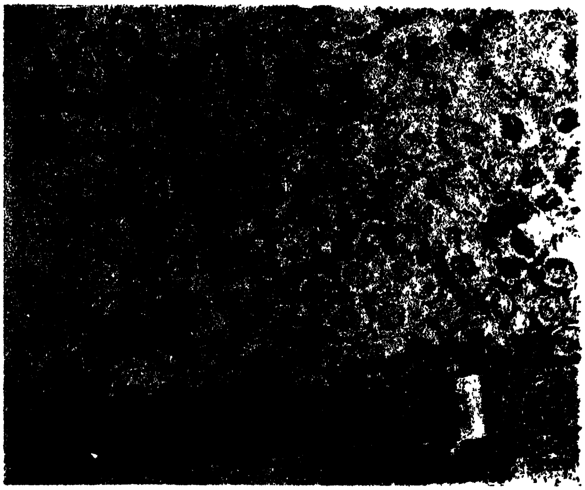

FIG. 2.—*Balanus balanoides* on rocks at Port Erin, nat. size.

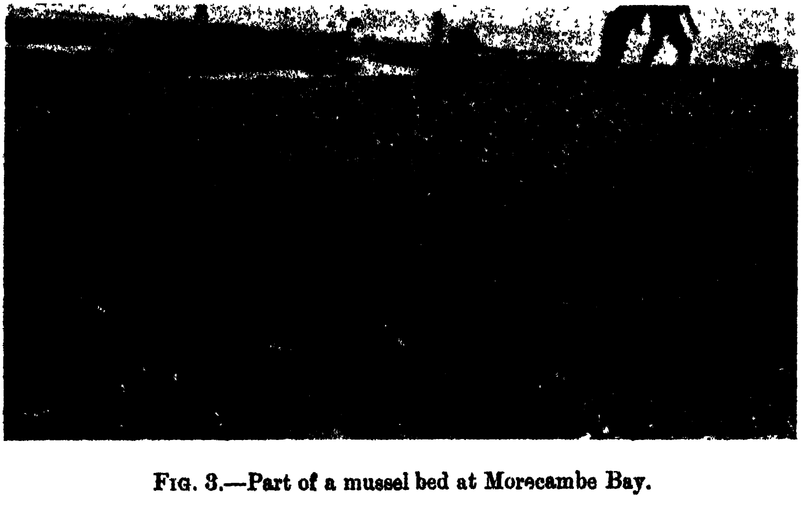

FIG. 3.—Part of a mussel bed at Morecambe Bay.

Balanus must be of value as a food-matter, not only directly if crunched up or sucked out of its calcareous covering, but also indirectly through its free-swimming larvæ. In early spring it sets these free in the Nauplius stage in such abundance that the water close to the barnacle zone, or in any shore-pools of the neighbourhood, looks muddy, and when dipped out in a glass jar, is seen to be crowded with dense swarms of the minute larvæ.

They form a conspicuous feature of the plankton for a few weeks in March and April, and constitute, no doubt, an important food-matter at this time when there are comparatively few Copepoda available.

MYTILUS.

Probably the edible mussel (*Mytilus edulis*) is the most abundant mollusc in the seas of North-West Europe, and it is certainly the most generally useful to man, both directly as a food and as a fisherman's bait and also indirectly as the food of marketable fishes. Although mussel "beds," "scars," or "scalps," as they are variously called, are regularly worked over by the fishermen, they cannot be regarded as in any sense artificial. The mussels have settled down and grown upon them naturally. It is only very rarely that any transplanting takes place, and there is nothing in this country comparable with the artificial "bouchôt" system of mussel culture which takes place in the bay of Aiguillon on the west coast of France.

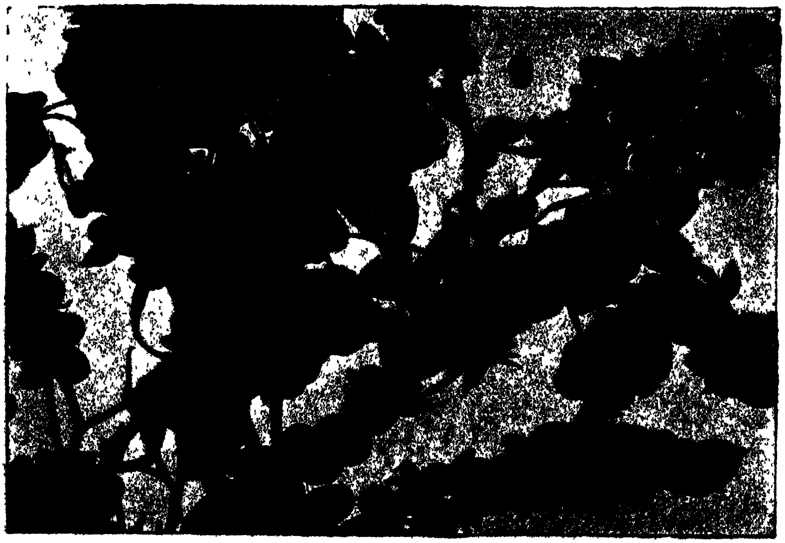

FIG. 4.—Mussel "spat" on sea-weeds, magnified.

In a mussel bed (fig. 3) not only are the mussels so closely placed as to be touching their neighbours all round, so as in some cases to cause distortion and prevent proper growth, but they are even piled on the top of one another, it may be several layers deep, the interstices below being filled up with mud and the byssus fibres of the molluscs in the layers above.

At the time when the mussel "spat" is settling down from the free-swimming larval condition, sea-weeds, zoophytes, rocks, and other objects between tide-marks may become covered with a layer of the little black dots as if they had been thickly peppered over (fig. 4); and in favourable localities the young mussels grow in a profusion which may cause their own destruction. I have seen the rocks at Hilbre Island covered with a layer of small mussels from a quarter to half an inch in length, which are so closely placed as to be absolutely continuous, and to be tightly united to one another by matted byssus fibres, while they have little or no attachment to the rock beneath, the result being that in the first storm the waves roll up the sheets of mussels and wash them ashore on the neighbouring sandy beaches in masses as large as pillows and bolsters.

In such sheets and masses I have counted from 80 to 100 mussels visible on the surface of a square inch, and in the case of slightly older ones from 50 to 60 (fig. 5). At the rate of 100 there would be about 129,600 in a square yard, and there are very many such square yards around our coast. No doubt the majority of these young mussels never grow to maturity. They are killed by storms, smothered by their neighbours, or eaten by star-fishes or by plaice and other fishes. In the latter case they are not lost as a food matter, and even in the former their remains will be eaten by something which will indirectly feed man. Nothing is lost in the sea, and everything ultimately in the metabolic cycle contributes to man's harvest.

FIG. 5.—Young mussels on *Laminaria* stem, nat. size.

Dr. James Johnstone has estimated* that a Lancashire mussel bed may have 16,000 mussels to every square foot, and that the proteid contents of the mussel flesh is comparable with that of a lean farm animal, while per unit of area the mussel bed produces nearly a hundred times the amount of flesh for food that is produced by cultivated land. The sea when cultivated, or when populated under favourable conditions as on a mussel scalp, seems to be more productive than the land *.

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* 'Conditions of Life in the Sea,' Cambridge University Press, 1908.

STYELOPSIS.

One of the most densely-covered rock surfaces that I have seen is in the large caves near Spanish Head at the south end of the Isle of Man. These caves have to be entered by boat at low tide, and are of considerable extent, and their walls between tide-marks and as far down as can be seen in the clear deep water are covered with an assemblage of animals, consisting of: the Tetractinellid sponges *Pachymatisma johnstoni* and *Stelletta collingsi*, several species of small white calcareous sponges, *Halichondria panicea*, *Tubularia indivisa*, *Sagartia miniata*, and enormous quantities of the small red Ascidian *Styelopsis grossularia*. The Ascidians cover by far the greater part of the rock, and are so closely placed that their bases are continuous, and masses can be peeled off in small sheets (fig. 6). On the average of a number of measurements they are three-quarters of an inch in height, and there are from 10 to 30 in the square inch according to size, over 50,000 to the square yard.

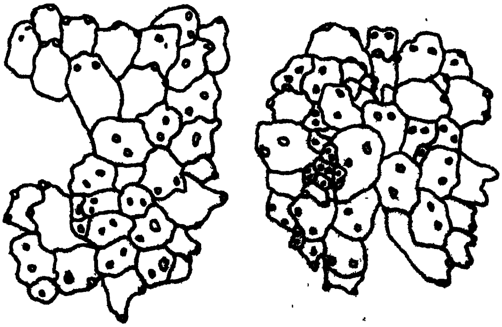

FIG. 6.—Two aggregations of *Styelopsis grossularia*, nat. size.

Although *Styelopsis* is not generally supposed to be a common animal, the numbers present in these caves, and no doubt in many other similar places on rocky shores, must be very large, and must afford a very considerable amount of highly nutritious food. In many parts of the world Ascidians closely related to our *Styelopsis* (Cynthiadæ) are used as food by man.

OTHER COMMON SHORE ANIMALS.

It may be of interest to add here the results of countings of a few other common shore animals, although I shall not discuss them further. Along with *Balanus* on the rocks (fig. 7), the most abundant shell-fish are *Patella vulgata*, *Purpura lapillus*, and several species of *Littorina*. Ten counts of *Patella* gave an average of 29 to the square foot, the highest record being 37. Two counts on square feet where *Purpura* seemed numerous on the limestone rocks at Port St. Mary gave 72 and 101 respectively. The method adopted in all these cases was to plant a wooden frame measuring one square foot internally down on the rock and count or remove all that lay inside it.

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* As Spenser seems to have known, or imagined, more than four hundred years ago:—

"O what an endlesse worke have I in hand,
To count the seas abundant progeny,
Whose fruitful seede farre passeth those in land," &c.—
Faerie Queen, Bk. IV. Canto 12.

In half-a-dozen small shallow rock-pools on the limestone at Port St. Mary the common red anemones (*Actinia equina*) gave respectively 30, 47, 60, 49, 55, 37 to the square foot, taking the pools in order from the highest downwards towards low water. The average is over 46, and the range (30 to 60) is not great—suggesting that such little pools having a surface of about two square feet and a depth of a few inches, and generally lined by Nullipores and Corallina, can only support some 40 or 50 anemones each.

FIG. 7.—Rock surface at Port Erin covered with *Balanus*, *Patella*, &c.

On the sand at Port Erin the most conspicuous marks are the "casts" of the burrowing worm *Arenicola marina* (the fisherman's "Lug-worm"), and from our counts we find 11,800 worms in a rectangle measuring 100 yards by 30 yards at low tide—that is about four to the square yard; while a little further up the shore, in a square of 10 yards each way, we found 653, or 6½ worms to the square yard—and this, moreover, on an area where both the fishermen and the visitors were constantly digging the worms for bait. Very much larger numbers than these—up to 30 or 40 to the square yard—have been counted on some beaches, and Ashworth has estimated that at Musselburgh, in a zone at low tide about a mile in length, there are from 3 to 4 million worms*.

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* L. M. B. C. Memoir xi., Arenicola; 1904.

SOME ALGÆ.

On rocky or stony shores the most conspicuous organisms after the barnacles are the large brown sea-weeds—the various species of *Fucus* and its allies in the littoral zone and those of *Laminaria* at and below low-water mark. At Port Erin and Port St. Mary we have made many counts [*], and some weighings, of the plants of *Fucus* and of *Laminaria* cut off from sample square feet in different regions, and also of the epifauna associated with the Algæ. *Fucus* is most variable, ranging from 2 to 352 stalks to the square foot. *Laminaria* is more constant; our counts range from 6 to 36; but in a typical area of *Laminaria*-covered rock, such as on the lower limestone reefs at Port St. Mary, the latter figure or anything about 30 stalks to the square foot is usual. As the stalks are on the average half an inch in diameter, this distribution means that they are scattered from 1 to 2 inches apart over the square foot (fig. 8).

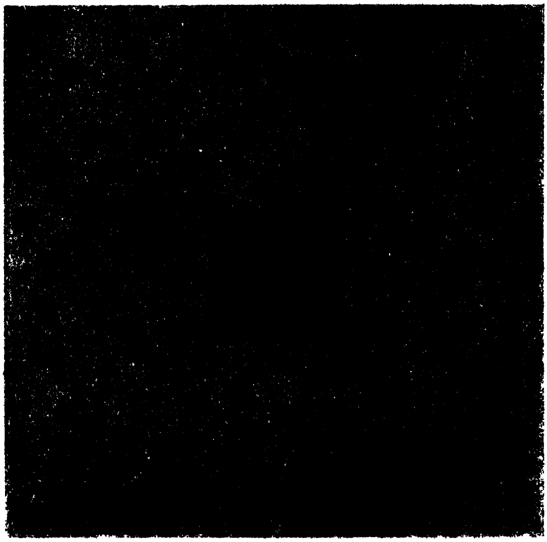

FIG. 8.—Diagram showing distribution of *Laminaria* stalks in one square foot. The black square in centre shows the area they would occupy if placed together.

The fronds of the *Laminaria* springing from the one stalk may be wide-spreading, and anything from 3 to 6 feet in height. Moreover, they may support an epifauna and epiflora of many molluscs, worms, polyzoa, hydroids, and smaller Algæ. We have made a number of measurements

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[†] I am indebted to one of my students at Port Erin, Miss Catherine Mayne, B.Sc., for much help with these counts and for a series of diagrams like figure 8 illustrating the density of distribution.

and weighings at Port Erin, but the results vary greatly with the amount of moisture retained by the Algæ. The general conclusion, however, is that a very large amount of organic food must be present in the region of the coarse brown sea-weeds, and especially in the Laminarian zone, and therefore it is not surprising that shoals of young fishes are found feeding there.

ZOSTERA.

The "Grass-wrack" (*Zostera marina*) is a flowering plant allied to the sedges, which grows in muddy sand at and below low-water mark. It is enormously abundant in certain places, and in the South of Australia I have seen banks of it several feet high extending for miles along the sandy beach. Petersen says that about 2000 square miles are covered by *Zostera* in Danish seas, that in the Kattegat alone it amounts to 24 million tons, and that it produces annually four times as much dry vegetable matter as all the hay on the land of Denmark. It is evidently the fundamental plant-food for fishes and other animals in the Danish seas, and no doubt it serves the same important purpose on a smaller scale in our seas.

There is a small *Zostera* bed in Port Erin Bay, and three patches at the mouth of Port St. Mary Harbour which are just accessible by wading at the lowest spring-tides, and there are much larger beds elsewhere further north on the shores of the Isle of Man.

A *Zostera* bed always supports a large fauna or epifauna associated with its roots, rhizomes, and leaves. Characteristic animals are the anemone *Anthea cereus* (= *Anemonia sulcata*), various species of *Trochus*, *Littorina* and *Lacuna*, some nudibranchs, many worms, zoophytes, polyzoa, and compound ascidians, especially the transparent *Diplosoma*. In addition, there are delicate filamentous Algæ (Confervæ) and enormous masses of Diatoms attached to the older withered or decaying leaves. Even after the *Zostera* leaves have decayed and gone to pieces, they contribute to the important organic detritus on the bottom, upon which many creeping animals on the surface of the sand are nourished. So that both directly and indirectly, through the organisms it attracts and supports, the *Zostera* bed is an important source of food to fishes and to many invertebrates.

The long blades or leaves, which may extend from 3 to 5 or 6 feet above the sand, arise in shoots from a creeping rhizome, and in my counts I find from 4 to 6 leaves in a shoot and about 20 shoots in an area of 3 inches by 1 inch—that is, about 1000 shoots in the square foot. The waving forest so produced, clothed in turn with many other organisms large and small, is one of the densest masses of living food-matter that I know of in the sea. The value of the *Zostera* bed in nature, both directly from the food that it furnishes to the animals living on it, and also indirectly from the enormous quantities of Diatoms which cover its decaying leaves, is a part of the metabolism or domestic economy of the sea—the computing of income and expenditure so as to find out whether we have a balance to the good, and whether the sea could be made by further cultivation to produce still more food for the service of Man.

CONCLUSIONS.

From these and similar data which can be readily obtained, it is not difficult to calculate totals by estimating the number of square yards in areas of similar character between tide-marks or in shallow water. And from weighings of samples some approximation to the number of tons of available food may be computed. But one must not go too far. Let all the figures be based upon actual observation. Imagination is necessary in science, but in calculating a population of even a very limited area it is best to believe only what one can see.

Countings and weighings, however, do not give us all the information we need. It is something to know even approximately the number of millions of animals on a mile of shore and the number of millions of tons of possible food in a sea-area, but that is not sufficient. All food-fishes are not equally nourishing to man, and all plankton and bottom Invertebrata are not equally nourishing to a fish. At this point the biologist requires the assistance of the physiologist and the biochemist. We want to know next the value of our food matters in proteids, carbohydrates, and fats, and the resulting calories. Dr. Johnstone, of the Oceanography Department of the University of Liverpool, has already shown us how markedly a fat summer herring differs in essential constitution from the ordinary white fish, such as the cod which is almost destitute of fat, as follows:—

	Herring.	Cod.
Proteids	21	16·7
Fats	22	0·3
Ash (+ salt)	9	1·3
Water (+ traces)	48	81·7

Prof. Brandt, at Kiel, Prof. Benjamin Moore, at Port Erin, and others, have similarly shown that plankton gatherings may vary greatly in their nutrient value according as they are composed mainly of Diatoms, of Dinoflagellates, or of Copepods; and Prof. Moore has kindly analysed for me, recently, samples of zoo-plankton (*Calanus*) and phyto-plankton (Diatoms) which I had collected in the Irish Sea for the purpose and transferred in the living condition into absolute alcohol. His results are as follows * :—

	Proteids.	Carbohydrates (by difference).	Fats (+pigment).	Ash.
Phyto-plankton (*Chætoceros*)...	31·6	29·7	24·2	14·5
Zoo-plankton .. (*Calanus*)....	53·1	18·2	17·6	11·1

And, no doubt, the animals of the benthos—the common invertebrates of our shores—will show similar differences in analysis †. It is obvious that some contain more solid flesh, others more water, in their tissues, others more calcareous matter in the exoskeleton, and that therefore weight for weight we may be sure that some are more nutritious than the others; and this is probably at least one cause of that preference we see in some of our bottom-feeding fish for certain kinds of food, such as Polychæt worms, in which there is relatively little waste, and thin-shelled Lamellibranch Molluscs, such as young mussels, which have a highly nutrient body in a comparatively thin and brittle shell.

I am aware that I am presenting a somewhat incomplete investigation, but my object is to direct attention to what seems an obvious and useful extension of faunistic work, for the purpose of obtaining some approximation to a quantitative estimate of the more important animals of our shores and shallow water and their relative values as either the immediate or the ultimate food of marketable fishes.

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* These figures differ somewhat from those given by Brandt, and this may possibly be due to differences between these types of plankton at Kiel and in the Irish Sea—which raises the interesting question whether the same organism may have different nutritive values under different hydrographic conditions.

† Moore and others have made analyses of the protein, fat, &c., in the soft parts of Sponge, Ascidian, *Aplysia*, *Fusus*, *Echinus*, and *Cancer* at Port Erin, and find considerable differences—the protein ranging for example from 8 to 51 per cent and the fat from 2 to 14 per cent (see Bio-Chemical Journ. vi. p. 255).

The Germ-Cells, Fertilization, and Early Development of *Grantia* (*Sycon*) *compressa* *. By J. Bronté Gatenby, B.A., B.Sc., D.Phil., Senior Demy, Magdalen College, Oxford; Senior Assistant in Zoology, Lecturer in Cytology, University College, London. (Communicated by Prof. E. S. Goodrich, F.R.S., Sec.L.S.)

(**Plates 19–23**; and 4 Text-figures.)

[Read 11th December, 1919.]

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* [The materials and part of the reagents used in this research were purchased by a Government Research Grant of the Royal Society, for which I express my grateful thanks.]

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1. *Introductory.*

THE following investigation into the gametogenesis, fertilization, and early development of a common British sponge, *Grantia compressa*, constitutes the opening of a new field of research in sponge-embryology, for the new methods of cytology have been used with fruitful results, and for the first time.

Quite recently Professor Arthur Dendy has published a paper in the 'Quarterly Journal of Microscopical Science', on "The Gametogenesis of *Grantia compressa*," in which he has described many interesting facts. Only such problems as those not treated by Professor Dendy have been dealt with here: for a long description of the nuclear phenomena in the germ-cell cycle of a Sycon, Jörgensen's paper (**8 a**) may be consulted.

In this paper I am able to announce a remarkable discovery in the early stages of conjugation of the gametes in *Grantia compressa* and *Sycon ciliatum*.

This work was partly carried out at Oxford in Professor Sherrington's laboratory, but mainly at University College, London.

Some time was also spent at King's College, Strand, London, in going through some of Professor Dendy's preparations. It is a pleasure for me to acknowledge the great help I have derived from various discussions with Professor Dendy, who has carried out such valuable investigations on the Porifera. Professor Dendy has followed with much interest this application of the modern technique to sponge-embryology.

2. *General Statement of the Problems investigated.*

It is a well-known fact that the amphiblastula larvæ of the Syconidæ are formed mainly of two sorts of cells—flagellated and granular. According to previous investigations, the cytoplasm in the two sorts of cells is of different quality; it was to examine this phenomenon that the present work was undertaken. It was necessary to see whether, during cleavage, there was a special segregation in any blastomeres of granules or organ-forming substances such as occurs in Ascidia (**1**). In addition, it was planned to study the fate of the middle-piece of the spermatozoon during fertilization. As is now well known, some workers claim that the middle-piece of the animal sperm breaks up during fertilization, and growing in the egg-cytoplasm takes part in the phenomenon of amphimixis.

En passant, I examined the various statements with regard to the origin of the germ-cells in sponges. Dendy (2), in his late paper, supports Haeckel's view that the germ-cells are formed from metamorphosed collar-cells, a view which is strenuously opposed by the Neo-Weismannians. As the work progressed, I found that two well-known spongologists, Jörgensen and Görich, had made an extraordinary misinterpretation of the early stages in fertilization. This paper gives the first account of the peculiar fertilization of the sponge and of the spermatogenesis of a marine sponge.

3. *Previous Work.*

There is no previous work on *Grantia* (*Sycon*) executed by any observer acquainted with modern interpretation as to the bodies in the cell. There are, however, several papers by earlier authors which are important; I refer to those of Görich (6), Jörgensen (8a), Maas (10), and Dendy (2). Jan Hirschler (8) has examined the collar-cells of *Spongilla*, while various other authors have written papers on the development and larvæ. The papers of Görich and Jörgensen are reviewed by Dendy (2), and will only be mentioned in the text when necessary.

Maas (10) in *Sycandra raphanus* describes the maturation and fertilization. The sperm penetrates the egg before the formation of the second polar body. With regard to the entry of the sperm, he says: "Der Spermakern zeigt sich beim Eintritt bestehend aus einer einzigen dichten Chromatinmasse von Bohnenform und einem dahinter liegenden stark lichtbrechenden Körper, beides umgeben von Zone verdichteten Plasmas mit sehr intensiver radiärer Strahlung.". The "stark lichtbrechenden Körper" is the "Chromidium" of Jörgensen. The two pronuclei come to lie in the central region of the ovum, chromosomes appear in each, and the first segmentation-spindle is formed. Jan Hirschler (8) describes briefly the Golgi body in the flagellated cells of *Spongilla*. It lies beneath the collar, is spherical, and resembles that of the central capsule (idiozome) in many metazoan germ-cells. This author also notes small granules of mitochondrial nature. He describes no stages in gametogenesis or development. Dendy (2), in a late paper, describes the gametogenesis of *Grantia compressa*. He adopts Haeckel's (7) idea that collar-cells can metamorphose into germ-cells. He describes oogenesis in detail, deriving oogonia from collar-cells, "which accumulate reserve material, enlarge, withdraw their collars and flagella, become amœboid and wander into the mesoglea, re-entering the chambers before dividing mitotically into oogonia of the second generation." Dendy finds "chromidia" in the oocyte cytoplasm, which he thinks are formed by a "process of extensive chromidium-formation by extrusion of chromatin from the nucleolus into the cytoplasm." Dendy's "chromidia" are the mitochondria ; so far as I can make out, Dendy does not describe or figure true yolk, nor has any other author done so.

Dendy shows that during oogenesis young oocytes engulf entire cells, which are brought to them by special carrier (nurse) cells. This process is very peculiar, and, so far as I can remember, unique in the Animal Kingdom. Dendy also describes a remarkable process in which the nucleolus becomes squeezed out to form lumps, which are extruded into the cytoplasm, and from these lumps he considers the chromidia are formed.

In his plate 24, figure 52, he gives a drawing of what we now know to be the fertilization. Dendy tacitly accepted Jörgensen's interpretation of these stages, but did not make a special study of development later than the full-grown oocyte.

Dendy's account of the origin of germ-cells from collar-cells has not met with any sort of general acceptance, principally because English zoologists have allowed themselves to be influenced by Weismann's germ-plasm theory in an uncompromising form. More wlll be said of this matter later on. It is merely necessary to add that the other view about the origin of the germ-cells in sponges derives them from wandering amœboid cells of the mesoglea, and the wandering amœboid cells are themselves derived during early larval life from posterior granular cells or archæocytes (Minchin, 9).

Both Jörgensen and Dendy describe a process whereby a part of one of the pronuclei occasionally becomes separated, and lies in the cytoplasm as an accessory separate nucleus, or "karyomere." Such a phenomenon does not happen, according to my own observation, in healthy cells, and I consider that the "karyomeres" are possibly accessory sperm-pronuclei, and that such a cell as drawn by Dendy in his pl. 26, fig. 95, is a case of polyspermy.

Subsequently to the writing of the above, I have seen many of Professor Dendy's preparations showing young oocytes engulfing other cells (see (2) pl. 24. figs. 50 & 51), and have found similar stages in my own slides. I accept fully this part of Professor Dendy's account, and draw attention here to the extraordinary character of this phenomenon. The oocyte of *Grantia* is a veritable phagocyte, and markedly amœboid and peripatetic.

4. *Material and Methods.*

The sponges used for this research were procured from the Plymouth Biological Station during the months of July and August, 1919 ; the species used was *Grantia compressa*, sometimes known as *Sycon compressum*. Special fixatives with directions for use were sent to Plymouth, and the specimens were preserved there. I have to thank Dr. Allen, F.R.S., for seeing that my directions were carried out. For some reason or other many of the pieces of sponge showed signs of having died of asphyxiation, and, though the methods used are the best known to modern cytology, I cannot say that my material was, as a whole, completely satisfactory; I can only assume that some of the sponges were not transferred to the fixatives quickly enough after their collection. For this reason I have been somewhat handicapped, and have had a certain measure of difficulty in working out part of my results; nevertheless, among the large numbers of slides prepared some perfect examples were procured.

The methods which gave the best results, and which future workers may use with confidence, are as follows: (1) Champy-Kull; (2) Hermann—or Flemming—without acetic acid followed by two or three days' mordanting in 3 per cent. $K_2Cr_2O_7$; (3) Kopsch's original method. For these techniques see my late paper (**4**). In addition, I tried the method of Cajal and used glycogen techniques. I had access to Professor E. S. Goodrich's formol-Flemming material of *Sycon ciliatum*, and at a late stage of this work to Professor Dendy's slides. I also had at my disposal the sponge collections at Oxford, and at University College, London. I have therefore based my remarks and figures on a very extensive collection. On my Plates the collar-cells are drawn from some very successful Kopsch preparations.

5. *General Account of the Development of a Sycon, up to the Formation of the Free-swimming Amphiblastula Larva.*

The ovum undergoes total and regular cleavage, resulting in the formation of a hollow blastula lying beneath the collar epithelium, Pl. **21**. figs. 19, 20, 22, and 21.

For some time the walls of the blastula are formed of cells, which are subequal in size and general appearance (Pl. **21**. fig. 21).

Subsequently one hemisphere of the blastula, generally that which lies immediately beneath the nearest gastral cavity, and touching the collar epithelium, becomes modified to form a regular epithelium of deep cells, with small dense nuclei like those of the choanocytes; flagella soon appear on these cells.

The other hemisphere, generally that which lies away from the epithelium of the gastral cavity, and in contact with the mesoglea, becomes changed very little, its cells dividing less rapidly and remaining clearer and larger. Examined fresh, much pigmented yolk is seen to repose in the former (flagellated) cells, while such granules of yolk are less evident in the latter (granular) cells. According to the late Professor Minchin (**9**), the free-swimming larva contains three cell-elements, "columnar flagellated cells at the anterior pole, rounded non-flagellated cells at the posterior pole, and a central mass of granular amœbocytes." In all probability the latter are derived from the flagellated cells by a process of immigration inwards into the reduced blastocœl.

6. *The Structure of the Amphiblastula Larva.*

The amphiblastula larvæ of *Grantia compressa* develop under the flagellated collar-epithelium, and are partially or wholly surrounded by a capsule of nutrient squamous cells. In Pl. **23**. figs. 28 and 32 the capsule is marked LGC ; at first I believed that the capsule was really part of the larva—that is embryonic tissue—but Professor Dendy kindly pointed out its true nature ; this partly investing membrane is formed of maternal cells, and when the larva breaks forth from the sponge, the capsule is left behind. The subject of this nutrient capsule will be dealt with below.

When the larva, after having become free, is examined alive, it will be noted that the histocytes or flagellated cells, while being clear at their outer extremities, contain in their inner ends abutting against the blastocœl, a large number of brownish-yellow yolk-spheres : in other species of sponge-larvæ, the colour of the yolk may be much brighter. In the fresh, the archeocytes or posterior granular cells are found to contain fewer yolk-spheres, or at least they are not grouped in such a way as to form a conspicuous coloured band as in the flagellated cells.

Now if the sponge is fixed in Champy's chrome-osmium mixture, and treated as elsewhere described (4) by the Champy-Kull method, in the embryos true yolk is greenish-brown, mitochondria are red, and nuclear substance is bluish-green. Moreover, by the Flemming-without-acetic acid and Iron Hæmatoxylin method, the yolk is greenish-brown, the mitochondria are black. By Altmann's method, yolk is greenish-brown and mitochondria red.

As is well known, if one fixes the sponge in highly coagulative fluids such as alcohol, corrosive acetic or Bouin's fluid, the posterior granular cells become more chromophile and granular on staining than the flagellated hystocytes.

Nevertheless, I cannot say that this more marked granulation in the posterior cells is traceable to a greater content in the latter of either mitochondrial or yolk spheres. On the contrary, most of the granular cells contain fewer granules of yolk or mitochondria than the histocytes. This can be seen on examining Pl. **23**. figs. 28 and 32.

Some amphiblastulæ embryos prepared in alcohol and stained in carmine showed the posterior or lower cells much denser and chromophile than the flagellated cells, while yolk and mitochondria were absent or, at the best, hardly observable. I trace the difference in quality of the granular and flagellated cells not to their contained granules, but to certain differences in the ground-cytoplasm, which in the granular cells is coarser and more chromophile on fixation in alcohol-acetic-corrosive liquids.

The cytoplasm of the granular cells is extremely oxyphile, nuclei are amphophile and contain a true plasmosome ; in iodine the granular cells go much darker than the flagellated cells. The nuclei of the flagellated cells are basophile and the cytoplasm only faintly oxyphile. The mitochondria of the amphiblastula larva are not pigmented in the fresh state. In Pl. **23.** fig. 31 is drawn at a higher magnification a posterior granular cell. In this there are both yolk and mitochondrial spheres (Y and M) and also probably Golgi elements (GX) ; the nuclei of these cells are most characteristic, being large, pale, and with an open reticulum. By the chrome-osmium method of fixation, the ground-cytoplasm of these cells is quite smooth and fine.

The minute structure of the flagellated cell is interesting, for the yolk-granules are aggregated into a special group beneath the nucleus and at the inner pole of the cell, as in Pl. **23.** fig. 33, Y ; the mitochondrial granules also lie nearly in the same region. On the periphery of the flagellated cells are found certain enigmatic granules whose histochemical reactions are unlike those of either yolk or mitochondria ; these fine granules are marked OG in Pl. **23.** fig. 33.

The nucleus is formed of a dense basophil matrix in which a nucleolus is visible. On the outer side of the nucleus is a coarse granule from which originates the flagellum. This coarse granule is apparently the Golgi apparatus, which surrounds the centrosome (see GA in Pl. **23.** fig. 33).

Lying inside the small blastocœl are found a few small amœboid cells, which have a nucleus like that of the flagellated cell ; the cytoplasm of these cells is crammed with mitochondria; in Pl. **23.** figs. 28 and 32 such cells are marked GAM, and in Pl. **23.** fig. 30 one of these cells is drawn at a higher power. I could not find any yolk-granules in these cells—only mitochondria.

Apart from these three cell-constituents, the sponge larva, while still *in situ* within the maternal tissues, is found to be invested by a cell-capsule, as in Pl. **23.** fig. 32 at LGC ; these cells are seen to contain a large number of mitochondria of somewhat irregular shape; in imperfect preparations this layer early peels off from the posterior granular cells. In Pl. **23.** fig. 29 one of these capsule-cells is drawn at a higher power. They contain mainly mitochondria, but no certain yolk-spheres.

So far as I can understand, the capsule around the *Grantia* larva is formed just after the period of differentiation of the flagellated hemisphere, from amœboid elements of the mesoglea. The matter, however, is far from being settled. There is one point to which I must draw attention : the maternal nutrient capsule often simply surrounds the cells of the posterior pole of the larva as in Pl. **23.** fig. 32, but in other cases the maternal cells partly tend to penetrate between and well into the granular posterior cells as in Pl. **23.** fig. 28 at LGC. This matter will be further investigated by me.

7. *The Minute Cytology of the Gastral Epithelial or Collar Cell of* Grantia.

Hirschler (8) was the first to show the presence of a typical Golgi apparatus in the collar cell of a sponge (*Spongilla*). Unfortunately this able observer did not push his work very far, and we do not know in *Spongilla* in what way the Golgi apparatus is related to the centrosome or flagellum. The technique indicated for work on the Golgi apparatus of sponges is that of Kopsch (4); pieces of sponge are left for two weeks in 2 per cent. OsO_4 and then washed, dehydrated, and embedded in hard wax. The sections are cut as thinly as possible and may be treated in turpentine to clear them somewhat—five minutes is long enough for thin sections. In *Grantia* such preparations show the Golgi apparatus in the collar-cells in the same position as indicated by Hirschler for *Spongilla*. Pl. **19**. figs. 1, 2, 3, and 4 are drawn from preparations of collar-cells, to show their minute structure. In Pl. **19**. fig. 3 is a group of cells fixed in Hermann-without-acetic acid, mordanted in $K_2Cr_2O_7$ and stained in either Iron Hæmatoxylin or Altmann. The granules contained in these cells are, I believe, the true mitochondria. Hirschler (8) figures such fine mitochondrial granules in *Spongilla*, and I think there can be no doubt as to the presence of mitochondria in the flagellated cells of *Grantia*.

In Pl. **19**. fig. 2 is drawn a Kopsch preparation of *Grantia compressa* to show the Golgi apparatus; as in *Spongilla*, it is a spherical or irregular object lying on the periphery of the cell and staining dark brown or black in osmic acid. In these cells the other cytoplasmic granules become light brown. Pl. **19**. fig. 4 is a high-power drawing of a collar-cell treated by Kopsch. The Golgi apparatus is seen to be formed of a central archoplasmic sphere (AS), surrounded by a rind of Golgi apparatus substance (GA); this preparation was differentiated in turpentine, while the apparatus in Pl. **19**. fig. 1 A & B was left untreated.

In many cases, such as in Pl. **19**. fig. 1 A, it can be shown that the flagellum passes into the apparatus, but in others, such as in Pl. **19**. fig. 1 B, the centrosome is distinct from the archoplasm and lies on the nucleus. I think that in most examples the centrosome lies inside the Golgi-cum-archoplasm apparatus, and the filament issues from the latter. In Pl. **19**. fig. 4, below the apparatus at C ?, lay a granule which is possibly the centrosome. Now besides the mitochondria, which in some cases may be much finer than depicted in Pl. **19**. fig. 3, there are other much larger granules marked Y in Pl. **19**. figs. 1 and 4. These are difficult to distinguish from the mitochondria, and they may stain black by prolonged immersion in Iron Hæmatoxylin; by staining in Altmann they are not tinged, and then can be distinguished from the mitochondria. In Cajal's silver nitrate method the granules may go intensely brown or black. Such large apparently non-mitochondrial granules are possibly yolky bodies partly formed of a dense proteid basis, whence their histochemical behaviour.

Presumably these nutrient granules are the direct descendants of those yolk-spheres which one finds in the histocytes or flagellated cells of the amphiblastula larva (Pl. **23**. fig. 28, Y, and Pl. **23**. fig. 32, Y). Nevertheless, such large nutrient granules of the flagellated collar-cell of *Grantia* are not quite like the yolk-spheres of the embryonic histocyte ; the former granule has a heavier proteid basis, which takes crystal violet and hæmatoxylin, as well as occasional impregnation in silver nitrate. At one stage of this work I did not feel sure that the nutrient granule and the mitochondrium of the collar-cell could be distinguished from each other, but some of my later preparations appeared conclusive. Probably the most convincing evidence is acquired by examining two sets of preparations, one by the Kopsch, the other by the Flemming-without-acetic method (**4**). In the former, yolk or nutrient bodies are markedly demonstrated, in the latter such bodies are not properly shown, while mitochondria stain densely.

8. *Amœboid Cell-elements of* Grantia.

Besides the ordinary flagellated cells *in situ* lining the gastral cavities, one finds many wandering mesogleal cells whose origin can be traced to the flagellated cells, as depicted in Pl. **22**. fig. 24 (see also Pl. **19**. fig. 7).

Such amœboid cells are the commonest elements of the mesoglea and very probably give rise to both spermatozoa and ova. In addition to the ordinary amœboid cells, whose cytoplasmic inclusions much resemble those of the collar-cells, one occasionally finds small cells loaded with mitochondria. These granular cells are very distinctive, and examples of them are seen at GAM in Pl. **21**. fig. 21 and Pl. **22**. fig. 23. Such cells contain in their cytoplasm a large number of mitochondrial granules, and very little of any nutrient yolk-spheres. They are probably formed from the histocytes during late larval and early pupal life, as shown in Pl. **23**. fig. 28, GAM, and in Pl. **23**, fig. 30. I do not intend here to enter into the questions surrounding other elements of the sponge, but the two kinds of cells abovementioned are the only sorts of amœboid cells which have been met with by me, and which could give rise to gametes.

That the germ-cells may arise from the ordinary wandering mesogleal cell (Pl. **19**. fig. 7) is very probable, but the smaller and more densely granular cells are less common—so rare, in fact, that one could not believe that they provide a large quantity of germ-cells, if any at all.

9. *The Question of the Origin of the Germ-cells.*

That ova and spermatozoa ultimately arose from collared cells was the conclusion of Haeckel, but Schultze and others claimed that they arose from wandering amœboid cells of the mesoglea, which they supposed were unrelated to the collar-cells. Poléjaeff and Görich also consider that germ-cells arise from wandering mesogleal cells, which are not connected with the gastral epithelium. Jörgensen likewise derives his germ-cells from the so-called mesoderm (mesogleal) cells, either resting stellate connective-tissue cells, or amœbocytes. Dendy, as before mentioned, in 1915 published a paper in which he disinterred Haeckel's "heresy," and courageously stated that in his opinion collar-cells did metamorphose into germ-cells. In the present paper I am finally obliged to follow Dendy's unpopular view, simply because I find myself unable to overlook directly confirmatory evidence, derived from examination of my own and other workers' sections. It is my opinion that not only do collar-cells migrate into the mesoglea and subsequently become germ-cells, but also that collar-cells *in situ* may metamorphose into oogonia. Schultze, Poléjaeff, Jörgensen, and others may be correct in considering the germ-cells as originating from mesogleal amœboid cells, but I claim to have shown here that collar-cells are the main source of the above-mentioned amœboid cells, so that in the long run Haeckel and Dendy are correct.

10. *How Collar-cells become Amœboid Cells of the Mesoglea.*

In Pl. **22**. fig. 24 I have drawn by means of the camera lucida a part of a sponge showing the migration of collar-cells into the mesoglea. The cells marked *a* 1, *a* 2, and *a* 3 are three stages in the process; in Pl. **19**. figs. 7 and 8 are two later stages showing the matamorphosis of an amœboid cell into an oogonium. The cells drawn in Pl. **22**. fig. 24 can only be doing one of two things—either they are migrating into the mesoglea or they are migrating from the mesoglea to the gastral cavity. That they are not doing the latter seems indicated by the fact that just near the figure *a* 2 in Pl. **22**. fig. 24 are gaps in the epithelium showing that cells have left their place, and the cell marked by the figure *a* 3 is opposite one of these gaps. When the collar-cells begin to migrate inwards they lose their collar and flagellum and become amœboid. As Dendy and Carter showed, collar-cells teased out alive often begin to thrust out pseudopodia. Many amœboid cells of the mesoglea contain similar cytoplasmic inclusions to those of the ordinary collar-cells, but later their mitochondria often become more marked, as in Pl. **19**. fig. 7. Most of the pieces of sponge I have sectioned exhibit appearances such as drawn in fig. 24 of Plate **22**, and I am led to believe that this behaviour of collar-cells is of constant occurrence during the life of the sponge individual.

11. *Formation of Oogonia* in situ *from Collar-cells.*

In Pl. **22**. figs. 23, 25, and 26, I have drawn with the camera lucida parts of the gastral epithelium to show the metamorphosis *in situ* of collar-cells into oogonia. The first stage is in Pl. **22**. fig. 26 ; at PC, a collar-cell has sunk below or become partly covered by its immediate neighbours. That this cell, which is larger than ordinary collar-cells, is really a lately metamorphosed gastral epithelial cell is indicated, firstly because its nucleus resembles that of the collar-cell, and secondly because its cytoplasmic inclusions are closely similar to those of its neighbours. In Pl. **22**. fig. 25, the cell marked OG has a cytoplasm just like that of the collar-cell except that its size is greater; the nucleus of this cell is like the nucleus of the collar-cell, except for the size of the karyosome. In Pl. **22**. fig. 23 at PC and OG are two stages which are similar to those already described. The cell OG is now an oogonium, and is about at the same stage as that drawn in Pl. **19**. fig. 8. In Pl. **22**. fig. 27 at OTE is a still later stage.

The figures 23–26 of Plate **22** were drawn carefully with the camera lucida, from the edge of a sponge where a large number of young oocytes were found. All stages up to the formation of larger oocytes were present, and I believe there can be no doubt that such a cell as that in Pl. **22**. fig. 25 is a stage in oogenesis, and is derived from a collar-cell.

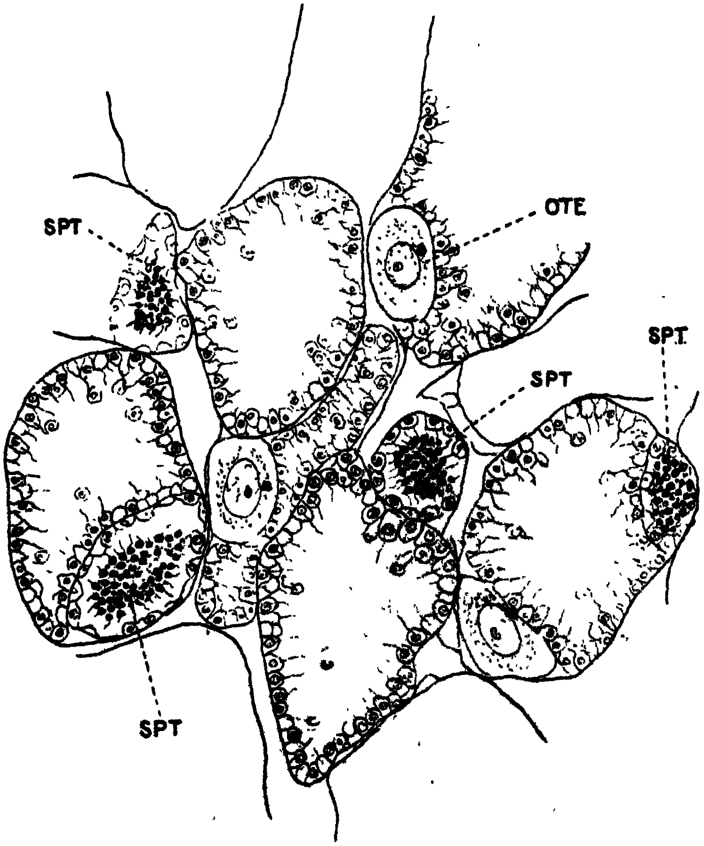
12. *Position of Germ-cells in* Grantia compressa.

In Pl. **19**. fig. 5 is part of a sponge showing an egg (OTE) on the left and a group of spermatids (SPT) on the right. These lie beneath the collar-cells, and tend to abut into the gastral cavity (GCAV). Jörgensen (**8 a**) mentions that oogonial divisions may take place in the gastral cavity beneath the collared epithelium, but more often in the mesoglea. The growing oocyte always occupies a position beneath the basement-membrane of the collar-epithelium, and I believe that it may come to lie in this position, in many cases by a simple sinking inwards as shown in Pl. **22**. figs. 25 and 26. Between the stages drawn in the latter figures and in Pl. **22**. fig. 27, OTE, Jörgensen finds oogonial divisions and the prophases of the first maturation division. These latter have occurred in Pl. **22**. fig. 27, OTE, which is well advanced in growth. Jörgensen would possibly interpret the cells marked PC and OGA in Pl. **22**. figs. 23, 25, and 26, as secondary oogonia which had migrated from the mesoglea to their present position ; this I would dispute, for I find all stages intermediate between such cells and the collar-epithelium cell. The migrations of the oogonia are very peculiar, and I cannot claim that this account is at all exhaustive. The problem is one which will need special study and a larger amount of material than at my disposal ; the main point is to note that collar-cells do not always remain as such, but may grow and metamorphose into other elements.

13. *Spermatogenesis in* Grantia compressa.

About twenty-five pieces of sponge were sectioned by me, and of these only one contained any obvious stages of spermatogenesis. The sperm-elements of *Grantia* consist of small groups of cells lying in the interstitia between the gastral chambers. Each group lies enclosed in a special capsule of mesogleal cells, the whole arrangement being unlike anything described by previous authors.

TEXT-FIG. 1.



Camera-lucida drawing of part of sponge showing oocytes (OTE) and nests of spermatids (SPT) with tails. Compare with Pl. 19. figs. 5 and 5 A. The entire substance of this sponge contained patches of spermatids and isolated growing oocytes; it was a slightly protogynous hermaphrodite, as some of the oocytes were being fertilized.

It is a moot point as to whether each group of sperm-cells should be called a testis; I think that the cells are too much scattered to form a distinct gonad (text-fig. 1).

In Pl. **19.** fig. 5 is depicted a part of a hermaphrodite individual showing one gastral cavitry, on the left an oocyte about to be fertilized, and on the right a nest of spermatids (SPT), enclosed by their nurse-cells (NSC). The latter are pale cells, cubical, and contain faint granulations; they are not ciliated and the epithelium they form may be partly interrupted by absence of cells at any one side.

The spermatids lie inside the cavity of the nurse-cell chamber (SPA), and their tails can easily be seen.

In my material I was in addition able to recognise larger cells also enclosed by a nurse-cell chamber—these I believe to be spermatocytes, as they are of the expected size.

These aggregations of sperm-cells probably arise at a certain period of the year from amœboid elements of the mesoglea, and the nurse-chamber would be formed subsequent to the inception of spermatogenesis.

14. *General Description of the Inclusions of the Cytoplasm in Oogenesis.*

The young oocyte of *Grantia* contains the usual three categories of cytoplasmic granules or bodies, *i. e.* yolk-spheres, mitochondria, and Golgi apparatus. In Pl. **19.** fig. 2 is a young oocyte containing three Golgi elements (GAO), with yolk and mitochondria stained yellowish. The apparatus is like that of the flagellated cells, being formed of an inner protoplasmic (archoplasmic) area, surrounded by a peripheral rind of Golgi material. My Kopsch preparations were not suitable to study the Golgi apparatus in all stages, because those which were successful did not contain oocytes older than that drawn in Pl. **19.** fig. 2.

The mitochondria I worked out fully: they are the "chromidia" of Jörgensen. Without clouding this present section with controversy with regard to the origin of the germ-cells, it can be stated that those cells (in fact, all cells of the sponge) from which the gametes ultimately arise contain mitochondria in their earliest stages. There can then be no question as to the origin of the sponge mitochondria from chromatin. The mitochondria in the young oocyte (Pl. **19.** fig. 8) may be extremely large and coarse, and they lie in the endoplasmic region. As the oocyte grows larger, the mitochondria become more numerous and generally smaller at first, but later they may grow very large and dense. As soon as the oocyte has grown so large that the crowding of the granules is less marked, vacuoles begin to appear in the endoplasm.

The yolk in the *Grantia compressa* oocyte cannot be demonstrated properly by short fixation in chrome-osmium, as is suitable for mitochondria. The best method for demonstrating yolk is the unmodified Kopsch (7).

In Pl. **19.** fig. 9 is an oocyte just before fertilization, showing the mitochondria (black) and the very fine numerous yolk-granules as lightly stained bodies. The yolk-bodies of the egg of *Grantia* are so delicate that only prolonged osmication enables them properly to withstand contact with alcohol and xylol in the subsequent embedding and staining. I have not hitherto met with such delicate yolk, though that of the mollusc eggsis often very easily destroyed. No other author has described the true yolk of sponge-eggs.

While the yolk granules are beautifully fine and regular in size and shape, the mitochondria are often extremely coarse, and of irregular shape, and may occasionally be abnormally large (Pl. **20**. fig. 13, M).

In the unfertilized and unmatured oocyte, the yolk granules and mitochondria are evenly distributed in the endoplasm, as depicted in Pl. **19**. fig. 9, and, as will be seen, are subsequently evenly sorted out among the blastomeres during cleavage of the ovum.

15. *Ectoplasmic and Endoplasmic Regions in the Egg.*

Even in the youngest oocytes one may notice that at an early stage a clear ectoplasmic zone becomes differentiated from an inner or endoplasmic zone. The ectoplasmic zone (Pl. **19**. figs. 5 and 9, Pl. **20**. figs. 10–13, Pl. **21**. figs. 18–20) contains few or no vacuoles, is smooth, and is often drawn out in the form of blunt pseudopodia or filamentous dendriform threads. The inner or endoplasmic zone is vacuolated completely and has a fine frothy appearance ; it is in this region that the cytoplasmic inclusions lie, granules in the ectoplasm of the oocyte being rare or never found. Occasionally, in preparations fixed in mixtures containing alcohol or acetic acid, the vacuoles collapse, and the egg comes to have a curious radiation of fibres around the nucleus (see Jörgensen's figures, 8 a). Eggs treated with silver nitrate solution show the endoplasm browner than the ectoplasm, and in some cases the difference in quality of ectoplasm and endoplasm is as marked as that shown in Pl. **19**. fig. 5, END, ECT. In favourable cases not only young oocytes, but amœbocytes, may be seen to possess ectoplasmic and endoplasmic zones (Pl. **19**. figs. 7 and 8). As in the case of the older oocyte the cytoplasmic inclusions lie in the endoplasm, while the pseudopodia consist mainly of ectoplasmic material.

During development of the egg, all the blastomeres in most cases come to have an equal portion of the ectoplasm.

The ectoplasm can be traced through cleavage up to the formation of a blastula (Pl. **21**. fig. 21), but it soon either becomes absorbed or is invaded by endoplasmic substance. In Pl. **21**. fig. 22, a young blastula is shown, which still has distinctly marked ectoplasmic regions. In a rare number of cases, it was found that in young blastulæ the cells of one side had less ectoplasm than those elsewhere, but in no example could I show that this inequality had any relationship to the formation of the flagellated and non-flagellated parts of the amphiblastula.

16. *The Problem of the Polarity of the Oocyte, the Ovum, and the Embryo.*

This important problem is very difficult to understand properly, because the granules in the *Grantia* egg are evenly disposed, and one cannot identify a vegetative or animal pole by this means. In fact, one is obliged to consider that the egg of *Grantia* is a primitive amœboid body, without visible signs of a polarity such as one finds in the amphibian egg (Pl. **19.** fig. 9).

In most cases the egg of *Grantia* lies beneath the gastral epithelium in such a way as to be compressed into an oval form, as shown in Pl. **19.** fig. 9; the nucleus itself is rarely quite spherical, being oval in the same direction as the egg. While some oocytes at this stage are quite spherical, and their nuclei likewise, it is true that by far the majority of *Grantia* oocytes possess this form of bilateral polarity. While the oocyte nucleus is most commonly oval or elliptical, the pronuclei are often quite spherical. Though it is difficult to come to a conclusion, I fear that the above observations on the gross polarity of the oocyte are of only small value.

The ectoplasm, too, lies around the entire periphery of the egg, and lends no clue to the solving of this problem. Polar bodies are most often given off towards the gastral side of the egg, but I know of one case where a polar body was passed out on that side of the egg lying towards the mesoglea. I do not consider that much significance can be attached to this.

I have been forced to the conclusion that, apart from the bilateral polarity caused by pressure, the oocyte shows no permanent signs of definite polarity.

Now during fertilization the sperm always, in my experience, enters at that side of the egg nearest the gastral cavity (Pl. **19.** fig. 9, S), and in by far the greater number of examples the penetration of the sperm causes a partial flow of cytoplasmic granules to that side of the oocyte on which the sperm entered (Pl. **20.** fig. 13). The egg thus comes to have a definite polarity temporarily conferred by the entry of the sperm. The question then arises as to whether the place of entry of the spermatozoon marks the animal pole, and whether it is the animal pole which later becomes the flagellated hemisphere of the blastula?

There are several established facts which we may notice at once: The flagellated half of the amphiblastula larva almost always becomes formed from that hemisphere of the undifferentiated blastula abutting against the gastral layer; the sperm always enters on this same side, and the polar bodies are most often given off on this side; in the differentiating blastula (Pl. **22.** fig. 27), the line of demarcation between future flagellate cells and future granular cells is sharply distinguishable.

I may say, nevertheless, that I am aware that the above evidence is insufficient fully to settle the question of the polarity. One may, however, follow out this line of reasoning to its fullest extent, though it should be noticed that the constant position of entry of the sperm may only be due to the fact that the gastral side is the nearest path which the sperm could take to the egg.

The fertilized egg soon loses that temporary polarity conferred by the disturbing influence of the spermatozoon, and soon the granules so disarranged flow back and become evenly disposed (Pl. **21**. figs. 18 and 19). No methods used by me succeeded in demonstrating any differences in cells of the two halves of the early blastula (Pl. **21**. fig 21), and it should be mentioned that in several cases it seemed to me that the future flagellate hemisphere, instead of being turned towards the nearest gastral cavity, was turned away from it, as drawn in Pl. **22**. fig. 27, where I presume the spermatozoon entered near the letters SPX.

The conclusion which seems most likely to be correct is that the oocyte lies with its animal pole towards the gastral cavity, and that the sperm enters at this pole; one may also suppose that the animal pole gives rise to the flagellated cells or histocytes, while the vegetative hemisphere gives rise to the granular cells. It may be noted, too, that the oocyte cytoplasm shows, on a microscopical basis, no signs of regional differentiation.

I believe that while the latter remark is correct, it may be true that the ground-plasma of the oocyte is more or less perfectly differentiated into two sorts of substances, which may be the forerunners of the two different categories of cells of the amphiblastula larva.

17. *Preliminary Outline of Events leading to the Union of Sperm and Egg.*

The following account of the stages leading to the union of sperm and egg is derived only partly from assumption, but mainly from actual observation of microscopical preparations.

The spermatozoa are carried into the gastral cavities, presumably being borne along by the inhalent currents. Passing to that region of the gastral epithelial carpet overlying a ripe oocyte, one spermatozoon enters a collar-cell (Pl. **19**. fig. 9). After the entry of the sperm into the choanocyte or collar-cell, the latter loses its collar and flagellum, becomes amœboid, and gradually passes through the basement-membrane of the collar-cell epithelium (Pl. **20**. fig. 14), and penetrating all obstacles finally comes to lie on what I have tentatively presumed to be the animal pole of the egg: generally the sperm-carrying collar-cell makes a special depression on the surface of the oocyte. Protoplasmic continuity is established between oocyte and sperm-carrying cell, and the spermatozoon is passively borne into the egg by means of protoplasmic currents (Pl. **20**. fig. 12).

In short, this account would mean to say that the differentiated flagellated collar-cell may become modified, in a short space of time, into an amœboid non-flagellated cell, whose function is to carry the spermatozoon to the egg.

I consider that I have found all stages confirming this peculiar happening, not only in *Grantia*, but also in part in *Sycon ciliatum*. Jörgensen's figures (**8 a**), misinterpreted, show that the same process takes place in *Sycandra raphanus*.

18. *Evidence as to the True Identity of the Sperm-carrying Cell.*

In by far the greater number of cases, the earliest stages of fertilization that I have found are those at a time when the sperm-carrying cell has reached the egg (Pl. **20.** figs. 11 and 14). In many such cases it is quite clear that the nucleus of the sperm-carrying cell has a somewhat clearer substratum, and may be bigger than that of the collar-cell. Did one know only these special cases, one might be led to consider that the sperm-carrying cell was some sort of amœbocyte from the mesoglea. Nevertheless, I have concluded definitely that the sperm-carrying cell is, or was, a collar-cell, and for the following reasons :—

1. In certain few but definite examples the ripe spermatozoon has been found in a collar epithelial cell, which reposed in place alongside its fellows (text-fig. 1, camera lucida).
2. In a very large number of examples I found spermatozoa in cells in the position indicated in text-fig. 3—that is to say, still in the epithelium, but more or less covered by its neighbours.
3. In a very large number of cases, I believe the majority, the nucleus and the cytoplasmic inclusions of the sperm-carrying cell exactly resembled those of the collar-cell or choanocyte, while the size of the former approximated closely to that of the latter (see page 279).
4. The position of the point of entry of the sperm-carrying cell into tissue of the sponge, on its journey to the oocyte, is remarkably constant (compare text-fig. 4) ; yet when one examines ripe oocytes before the advent of the spermatozoon, no special cells can be found in the epithelium at the region where the sperm-bearing cells later appear.

These reasons lead me to believe that the sperm-carrying cell is a modified choanocyte ; I consider that any one of the statements given in the above four paragraphs is sufficient to indicate the true nature of the sperm-carrying cell, and all the facts together constitute a clear and indisputable proof.

The occasional slight change in the density of the nuclear substratum (linin) I consider explicable under the assumption that the presence of the spermatozoon exerts an influence leading to this change, and it is important to note that this change does not always occur.

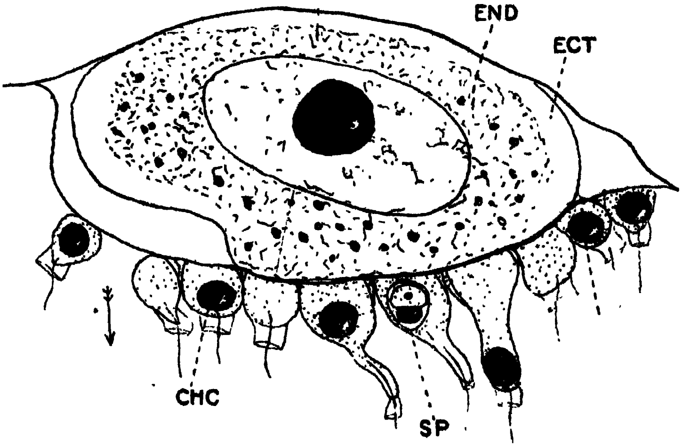
The matter is further discussed on page 283.

19. *Behaviour of Sperm after Entry into Collar-cell.*

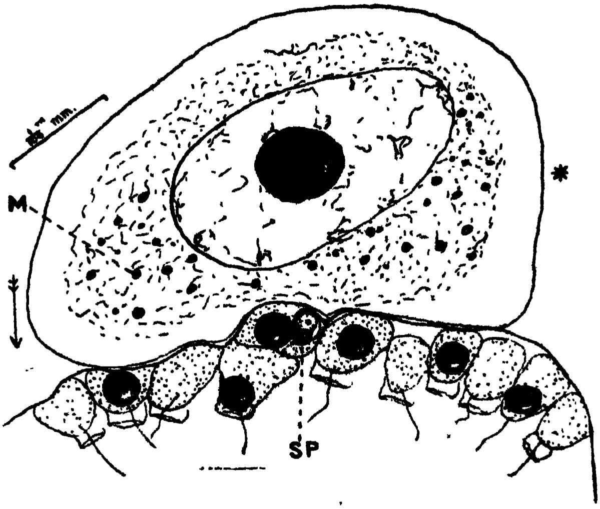
In my own preparations I never found the last stages in spermatogenesis, so that it is impossible for me to say whether the nucleus of the sperm is altered by its entry into the collar-cell. In Pl. **19.** fig. 5 A, I have drawn

TEXT-FIGS. 2-4.

2.



3.



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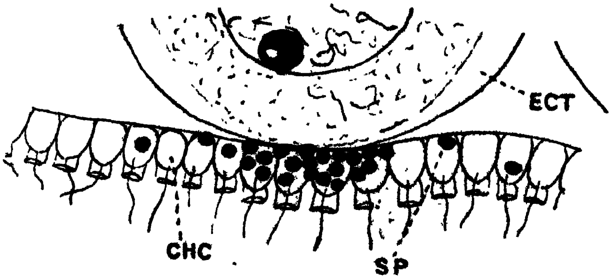

Letters CHC = collar-cell of gastral epithelium. ECT and END = ectoplasmic and endoplasmic regions of oocyte. M = mitochondria. SP = spermatozoon.

Figs. 2 *and* 3.—Two stages in the fertilization of *Grantia*; in fig. 2 the spermatozoon (SP) has just entered a collar-cell; in fig. 3 the collar-cell has lost its collar and is sinking below its fellows. Subsequent stages are drawn on Pl. 20. figs. 12, 16, and 17.

Fig. 4.—Part of an oocyte and the covering-wall of collar-cells (CHC). The black dots represent the comparative positions of twenty-five spermatozoa in that number of cases examined in the stage drawn in fig. 3. In all I have over fifty oocytes in stages at or between Text-figs. 2 & 3 and Pl. 20, fig. 11.

the oldest spermatids I could find, and in Pl. **19**, fig. 6 I have drawn the sperm possibly just after it has entered the collar-cell. The tail of this sperm has been added to my drawing. From what evidence I gained by examining a number of ripe sperms lying in collar-cells, I believe that the only change undergone by the sperm in this position is the loss of its tail or axial filament. The nucleus of the sperm, after entry into the collar-cell, might swell a little, but I have no evidence that such is the case*. It is only when the sperm is drawn into the egg that the former breaks into parts, and the nucleus begins to swell. The collar-cell has no such effect on the sperm: this is a very interesting point.

Görich, however, in *Spongilla* draws the sperm quite differently from that of *Grantia*, and if the free sperm of the latter resembles that of *Spongilla* it is certain that some change comes over the *Grantia* sperm after entry into the collar-cells. Görich's account I do not trust in details.

20. *Changes in the Collar-cell brought about by the Entry of the Spermatozoon.*

While most sperm-carrying cells at the stages drawn in text-fig. 3 closely resemble the collar-cell, it is true that by the time the former reach the oocyte some undoubted changes have taken place, especially within the nucleus.

The example drawn by Professor Dendy (**2**) on Pl. **26**. fig. 52 of his paper is a fairly typical case, such as I have occasionally noted in my own material; a similar example is drawn on Pl. **20**. fig. 16 of this paper.

I find that a good deal of variation in the general appearance of the nuclei of the sperm-carrying cell can be noted, and some nuclei are exactly similar in size, shape, and staining-power to the collar-cell nucleus, while others lack especially that dense substratum peculiar to collar-cell nuclei. I consider that this partial clearing-up of the dense nuclear substratum is caused by the prolonged presence of the sperm, and is in some way connected with the amœboid phenomenon of the metamorphosed collar-cell.

In addition to this occasional change, all sperm-bearing collar-cells lose their collar and flagellum, and become amœboid. As would be expected, most sperm-bearing cells are a little larger than the unmodified collar-cell: this is due to the presence in them of the sperm.

21. *The Fate of the Sperm-carrying Cell after the Sperm passes into the Oocyte.*

The sperm-carrying cell lying upon the surface of the oocyte is a most conspicuous object, yet in the cleavage-stages subject to fertilization this cell could not any longer be made out. Having examined a number of early cleavage-stages I have come to the conclusion that the sperm-carrying cell either wanders away after the spermatozoon has passed out of its cytoplasm, or in some way effaces itself by degenerating or shrinking in size. I found only one case suggesting that the sperm-carrying cell subsequently degenerates: in Pl. **21.** fig. 18, the cell at SCC is obviously unhealthy. At present I am led to consider that the sperm-carrying cell subsequently wanders away through the mesoglea.

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* I have lately procured evidence that the sponge sperm is filiform and flagellate, so a great change comes over it after entry into the collar-cell (see Journ. Roy. Micr. Soc. 1920).

22. *Behaviour of Sperm and Sperm-bearing Cell explicable as a Chemotactic Phenomenon.*

In text-fig. 4 is drawn diagrammatically a part of an oocyte and the neighbouring row of collar-cells. Twenty-five oocytes were examined at the stage of fertilization drawn in text-fig. 3, and the position of the sperm was indicated in the diagram in fig. 4 by a black dot. This diagram, therefore, gives a graphic representation of the fact that the swimming spermatozoon is definitely attracted in some way towards the egg. If this were not so, one would not find the sperm almost invariably entering cells neighbouring the egg. I have not found sperms in collar-cells further away from the egg than those drawn on the extreme left and right in fig. 4.

Chemotaxis as an explanation of the attraction of any sperm by any egg has been abandoned to a great extent by zoologists, but surely here is a definite case of attraction between egg and sperm? The egg of the sponge seems able to give forth some substance which causes the sperm to swim to that region of the gastral epithelial carpet which just overlies an oocyte. I cannot think of any other explanation which accounts for text-fig. 4 so satisfactorily.

23. *The Entry of the Spermatozoon into the Egg and the Effect on both Gametes.*

The sperm is drawn into the unmatured oocyte probably by synchronous flowing movements of the protoplasm of both sperm-carrying cell and the oocyte. That the sperm itself has no immediate part in the process seems indicated by the fact that it is able to pass into the egg with its nucleus forwards or its middle-piece forwards (Pl. **20.** fig. 11) or sideways. There is undoubtedly a complete protoplasmic continuity established between the cytoplasm of the carrier-cell and that of the oocyte; here the vitelline membrane of the egg is interrupted as shown in Pl. **20.** figs. 12 and 14.

When the sperm has passed into the egg, the first change noticed in it is the breaking-down of the sperm-cell wall (Pl. **20.** fig. 16). The acrosome (AC) becomes faint, and is just disappearing in the last figure. The sperm cytoplasm becomes furred at its edges where it touches the egg-cytoplasm; soon a flowing movement, apparently initiated by the entry of the sperm, tends to disturb the arrangement of mitochondria, which partly pass to that hemisphere of the oocyte at which the sperm entered (Pl. **20.** figs. 10, 12, 13).

Vacuoles collect near the region of the sperm, and the path of the latter into the egg becomes marked by an area formed of more liquid substance (Pl. **20.** figs. 13 and 17). The fine yolk-spheres keep closely around this area, but do not invade it, as is shown in Pl. **20.** fig. 13. Subsequent to the entry of the sperm, the oocyte undergoes maturation giving off two polar bodies.

24. *The Fate of the Middle-piece or Sperm Macromitosome ("Nebenkern") during Fertilization.*

In *Ascaris* and *Phallusia* it has been shown that the mitochondrial substance in the middle-piece of the spermatozoon does not degenerate during fertilization, but retains its faculty for growth and division and apparently takes some minor part in the phenomenon of fertilization (**14**).

With Champy-Kull technique the middle-piece of the *Grantia* sperm stains a bright red, while the egg-cytoplasm is a greenish or golden-grey colour; it is, nevertheless, a somewhat difficult matter to ascertain exactly what becomes of this body during fertilization. Between the stages of Pl. **20.** fig. 12 and fig. 13, the middle-piece in its form of a bun-shaped bead completely disappears. In Pl. **20.** fig. 17, MAM, it is quite clear that the middle-piece is breaking up into a cloud of small granules which adhere to the growing male pronucleus like the tail of a comet. In subsequent stages I never found any granules which I could identify for certain as having originated from the macromitosome, but in Pl. **20.** fig. 13, at *x*, are certain grains which might be the remains of the original middle-piece. While I do not wish to deny that there may be activity of the male mitochondria subsequent to the stage of Pl. **20.** fig. 17, I consider that such is unlikely. The evidence either way is not complete enough to allow me to express a definite opinion.

25. *The Mitochondria in the Development of* Grantia compressa.

In certain Ascidia it is established that the mitochondria become unevenly segregated into different blastomeres, the myoplasm being formed mainly from these granules. The two regions of the sponge amphiblastula do not contain granules in equal quantity, and it is interesting to ascertain whether in *Grantia* there is any special segregation of cytoplasmic granulations into special blastomeres.

Subsequent to fertilization in *Grantia compressa*, the mitochondria become more or less evenly spread out in the endoplasm (Pl. **21.** fig. 21), and during cleavage the distribution of the mitochondria between the blastomeres is equal, as shown in Pl. **21.** figs. 19, 20, 21, and 22.

In Pl. **21.** fig. 22, the blastula is found to be formed of cells, all of which contain approximately equal numbers of mitochondrial grains. It is only much later during the differentiation of the two main cell-layers in the embryo that any differentiation of granules appears, and these differences seem due to slow growth and not to any segregation during cleavage. It is apparent that *pari passu* with the cleavage of the egg into smaller and smaller blastomeres, the mitochondria either shrink considerably in size or break up into smaller fragments (compare the size of the granules in Pl. **21**. fig. 19 and fig. 22). It is not true that the mitochondria (chromidia of Jörgensen) disappear in the late blastula-stage, as was thought to be the case (8 a).

26. *Differentiation of the Nuclei of the Blastula-wall heralding the Formation of Two Definite Tissues.*

On Pl. **21**. fig. 21 I have drawn a *Grantia* blastula at a stage when all the cells appear alike; the nuclei and the inclusions of the cytoplasm of these cells seemed to me to be similar throughout the entire blastula. On Pl. **22**. fig. 27 is a blastula fixed at the period when the nuclei of the future flagellated hemisphere have begun to be easily distinguishable; the earliest signs of differentiation of the future flagellated cells is constituted by a tendency for the cells of one hemisphere to divide more rapidly, and to become more regularly arranged: the peculiar denseness of the nuclei of this layer is a subsequent and rapid differentiation. In Pl. **22**. fig. 27 the granules in the cytoplasm are not different in either region, and it seems certain that nuclear differentiation precedes or instigates special cytoplasmic activity.

Soon after the stage depicted in Pl. **22**. fig. 27, the character of the yolk-spheres becomes altered; this is indicated by the fact that the yolk-spheres of the embryonic tissues are more persistent and less easily destroyed than those of the egg or earlier blastula.

Owing to lack of suitable material, there were several interesting problems which I did not examine, but it is hoped to investigate these at some later period.

27. DISCUSSION.

(a) *Organ-forming Substances?*

In this study the behaviour of yolk and mitochondria has been followed out in the development of the sponge *Grantia compressa*. The introduction of specific and selective staining and fixing methods has enabled me to identify mitochondria, yolk, and Golgi apparatus. The sponge falls into the group of animal forms which have been shown to possess the two protoplasmic inclusions.

The main result of this research, in so far as it touches on the mitochondria, has been to show that they pass through development without losing their individuality, and that they are distributed evenly during cleavage to the blastomeres. No sort of segregation of materials in special blastomeres could be detected with the methods used by me, and I have come to the conclusion that such differentiation of cell-layers and materials as one finds in the amphiblastula larva is of gradual growth in the stages between the end of cleavage and the final stages of the formation of the free-swimming larva. I could not find any evidence for such segregation of materials as described by Conklin (1) in *Cynthia*, and I have come to the conclusion that, so far as fixed material goes, no visible organ-forming areas can be demonstrated in the egg of *Grantia compressa*. It is possible, however, that delicate easily destroyed pigments may be present in the fresh ripe egg, and these might mark out ground-protoplasmic areas not to be distinguished in fixed material. Of this I have no evidence.

(b) *Chromidia and Mitochondria.*

Jörgensen and Dendy both describe the mitochondria under the name "chromidia," implying that they have a true chromatinic nature and are related to the nucleus.

If the egg is treated by Champy-Kull's method the mitochondria are red (fuchsin) and the nucleus is bluish. In the Bensley-Cowdry stain the mitochondria are red (fuchsin) and the nucleus is green (methyl-green). In Carnoy's fluid the mitochondria are dissolved away and the nucleus remains. The mitochondria of *Grantia* are not "chromidia" in the proper sense of the word, nor are they derived from the nucleus at any period of oogenesis *. All embryonic cells contain mitochondria, and there is no question of the latter appearing from the nucleus at any stage of the oogenesis of egg-cells derived from the amœboid or other elements of the mesoglea or collar-epithelium.

In a late paper on *Apanteles* I described true cytoplasmic chromidia in the egg of this form ; such chromidia stain like chromatin, and ultimately metamorphose into secondary nuclei. In the Hymenopterous egg the secondary nuclei (chromidia) and the mitochondria are easily distinguishable and can be stained in different colours.

(c) *Fertilization.*

In this paper I have given the first correct interpretation of the peculiar stages already described by Görich, Jörgensen, and Dendy. It has been demonstrated beyond a doubt that the spermatozoon of *Grantia* is brought to the oocyte by a carrier-cell. On page 277 I have given my reasons for supposing that the sperm-carrying cell is really a collar-cell which has lost its collar and flagellum, and become amœboid.

Should subsequent work confirm this description (and I have little doubt that there has been no mistake) this will constitute one of the most remarkable occurrences in the fertilization of any animal.

It is remarkable that the collar-cell temporarily containing the spermatozoon should desert its position in the gastral epithelium and wander into the mesogleal tissue. That the sperm is the instigator of this unusual behaviour seems certain, and apparently any collar-cell may transform into a sperm-carrying cell. From examination of Dr. E. S. Goodrich's small series of *Sycon ciliatum* slides, I believe that in this form also the collar-cell acts as a sperm-carrier, and Jörgensen's account of similar stages in *Sycandra raphanus*, all misinterpreted, lead me to consider that the process described by me for *Grantia compressa* will apply to other forms of sponges.

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* I now abandon this view and admit Dendy's description of nucleolar extrusions to be correct. This matter is treated at length in my new paper in the Journ. Roy. Micr. Soc. 1920.

It is evident, as Professor Dendy has himself pointed out to me, that two distinct processes have been confused. The young oocyte is fed by a process of phagocytosis. It is definitely established by Professor Dendy that certain large amœboid elements of the mesoglea carry other cell-elements to the young sponge-oocyte, and the latter engulfs the food-matter so offered. The cell-elements which bring such cell-food to the growing oocyte are unlike the cell which later brings the spermatozoon to the oocyte ; moreover, this process of feeding only takes place in small oocytes. After the latter have grown to half their ultimate size, ingestion of other cells is rarely found to occur, and, moreover, ingestion of other cells by the growing oocyte takes place on any part of its surface, whereas the process of fertilization occurs on one definite side of the oocyte. There can be little doubt that not only is the process of phagocytosis in the oocyte different from the stages leading to fertilization, but also that the cells engaged in the two processes are not so alike as to lead one to believe that they are derived from the same source. The cells engaged in bringing food-matter to the young oocyte are nearly always much bigger than those which bring the sperm to the egg, and the cell-contents of the two cells are not alike.

(d) *The Sperm-carrying Cell considered as a Mesogleal Amœbocyte?*

The sperm-carrying cell has been assumed by me to be a modified choanocyte or collar-cell. There may be critics of this view who would prefer to take the other alternative, and look upon this peculiar cell as an amœbocyte from the mesoglea : according to such critics, the amœbocyte would be much more likely to behave in the manner of the sperm-carrying cells ; moreover, it is true that some of the latter have nuclei rather unlike those of the collar-cells, and similar to the true mesogleal amœbocytes.

In the first place, one never finds amœbocytes near unfertilized but ripe oocytes in the position in which the sperm-carrying cell later appears (text-figs. 3 and 4). Secondly, I have never found spermatozoa in amœbocyte elements of the mesoglea, and I have found several cases where sperms lie within what I presume to be choanocytes (text-fig. 2, SP). Thirdly, there is the fact that the position of the sperm-carrying cell is remarkably constant (text-fig. 4) : now, if mesogleal amœbocytes carry the sperm to the egg, why is this position so constant? Presuming that sperms swim through into the mesoglea and get into amœbocytes, we are then forced to believe that each sperm-bearing amœbocyte, whatever its primary position, always carries the sperm to one side of the egg; there would then undoubtedly be cases where the amœbocyte would have to perform a comparatively long journey with the opposite pole of the egg as its goal. Against this amœbocyte view there is a fourth reason: cells carrying sperms can never to my knowledge be found on the short "side" of the egg, as marked by the star on the right of text-fig. 3. Had the sperm-bearing cell been a mesogleal amœbocyte I would surely have found one with a sperm, in positions other than the gastral side of the oocyte (text-fig. 4).

Reference to Professor Dendy's pl. 24. figs. 50 and 51, and comparison with fig. 52, will show that the cell which carries food to the oocyte is not only bigger than that which carries the sperm, but has different cytoplasmic contents. In Prof. Dendy's fig. 52 the sperm-carrying cell (NC) is about the same size as a collar-cell.

To explain my text-fig. 4 satisfactorily on the basis of the amœbocyte view, one would need to assume that there was a row of waiting amœbocytes ready in the position in which the sperm is later found. No author who has drawn sponge-oocytes has figured such amœbocytes in this region, and I have never seen an amœbocyte waiting in this part of the gastral epithelium. To assume that the sperm pushes its way into the mesoglea till it finds an amœbocyte to carry it to the egg is preposterous, for if the sperm can push its way, "under its own power," into the mesoglea, there would be no need for another cell to carry it to the egg.

I think it will be obvious to all that the sperm does penetrate into a collar-cell, cannot itself pass through to the oocyte, but is carried by the collar-cell, which, during the process, may occasionally become somewhat altered in appearance.

(e) *Germ-cells and Sex in Sponges.*

My observations lead me to consider that all *Grantia* individuals are probably potential hermaphrodites, but that the occurrence of sponges with sperm-stages is somewhat rare. In only one case out of twenty-five that I know was the sponge a positive hermaphrodite, and in all the other examples I examined only oogenesis stages were discovered. I am led to consider that *Grantia compressa* is either a simultaneous hermaphrodite, or female, both sorts of individuals being found. The sponges which I found to contain oogenesis stages alone might have been either protandrous or protogynous hermaphrodites, but this seems rather improbable, for at the time I fixed my material the bulk of the oocytes were ripe and being fertilized, while there was a general absence of sperm-stages, except in one individual, which contained both spermatids and oocytes being fertilized.

One small point I may mention with regard to any possibility of self-fertilization in *Grantia*: the sole individual in which I found unripe spermatids also contained oocytes just being fertilized, showing that the sperms must have come from some other sponge, or otherwise one would have found later stages in spermatogenesis.

As a matter of fact, the whole question of sex in sponges is far from being definitely settled, for I doubt whether certain previous observers of marine sponges have really identified the true sperm-stages.

(f) *Spermatogenesis in* Grantia.

Haeckel in his 'Kalkschwämme' figures small "sperm-balls" just under the gastral epithelium, much in the same position as in Dendy's figures. Neither Haeckel nor Dendy have produced convincing evidence as to their "sperm-balls."

Subsequently to my writing the account of *Grantia* spermatogenesis given on page 272, I had the opportunity, through Professor Dendy's kindness, of seeing not only his own "sperm" stages, but also those of Dr. Poléjaeff. In figs. 86–93 of Professor Dendy's plate 26 are drawn what this observer describes as "sperm-morulæ," with spermatozoon heads; he has also described the derivation of these morulæ from other cells which he believed to be spermatogonia and spermatocytes. On pl. 26. fig. 94 he gives figures from Dr. Poléjaeff's slides. After carefully reading Dendy's account, and having seen his preparations, I have little hesitation in claiming that what he has described are certainly not sperm-stages of any sort; I believe that these bodies he describes are parasites or inquilines of some kind, probably of plant nature. Dr. Poléjaeff's sperm-balls are, I consider, nothing more than some protozoan, while the granules inside the cell are not individual cells, but discrete cytoplasmic aggregations. Moreover, neither Dendy nor Poléjaeff figure tails on their spermatozoa, while I find tails on my spermatids *.

I believe that there is no doubt that the cells I have described are true stages of spermatogenesis, and I sectioned twenty-five sponges before I found them. I wish to emphasize this fact, for other observers have found the same scarcity of spermatogenesis stages in sponges, and this is one reason why two observers (and probably three) identified either parasites or inquilines as sperm-stages.

Wilhelm Görich in *Spongilla fluviatilis* describes what are undoubtedly stages in spermatogenesis; his description of the formation of the spermatozoon from the spermatid is quite detailed, but he mentions neither mitochondria nor Golgi apparatus. In *Spongilla* the sperm-stages lie inside a wall of nurse-cells ("Cystenzellen"), somewhat as in *Grantia*. In *Sycandra raphanus* he describes the formation of the "Spermatocyste" by means of cell which approaches the spermatogonium ("Spermazelle"), and surrounds it completely; he figures and describes the sperm-cell dividing inside the cyst-cell. If Görich's account of the formation of the nutrient-cell capsule is correct, it would mean that in *Grantia* probably all the cells in Pl. **19**. fig. 5, marked NSC, would have originated from a single nurse-cell. I doubt this, but am unprepared at present either finally to reject or adopt Görich's account. In Görich's spermatid and spermatozoon there is no nucleolus.

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* At the meeting of the Society, after I had read this paper, Prof. Dendy, in reply, abandoned his previous views with regard to his "sperm-morulæ," and stated that in two other sponges he had found stages like those which I have described in this paper.

(g) *The Collar-cells as the Dominant and most Characteristic Tissue of the Sponge.*

Dendy (**2**) remarks, "The one constant and characteristic feature about sponge histology is, of course, the collared cell, and that is only constant in the sense that its typical form is that which possesses a collar and a flagellum. The sponge is, after all, not very much more highly advanced in organisation than a colony of choano-flagellate Protozoa." This paragraph aptly describes the views, at which I have myself arrived by my independent observation. The collar-cell is the dominant cell in the sponge, and I feel that Haeckel was correct in tracing the origination of germ-cells from collar-cells. Collar-cells are continually migrating into, and reinforcing, the mesoglea of the growing sponge; the collar-cell is really very little differentiated except for the flagellum and collar, which, we are now quite sure, can readily be withdrawn. The collar-cell then becomes an active amœboid cell-individual, whose subsequent fate possibly may be to metamorphose into a germ-cell.

One is obliged to remark that in the discussion on the origin of germ-cells—not only in sponges, but in other animals—there has been far too much reliance set upon theoretical conceptions, and not enough on simple observation. It does not suffice for critics to state that they "do not think that collar-cells can metamorphose into germ-cells"; they must bring forward something more definite before one can give their views adequate attention. So far as I am able to understand, the critics of Haeckel's view as to the origin of sponge germ-cells base their assumptions on the illogical and unnecessary extension of Weismann's views to sponge embryology. According to these observers, germ-cells are supposed to be derived from non-differentiated embryonic elements, and the collar-cell, having become differentiated, is debarred from entering the charmed circle of cells which alone can become germ-cells.

Speaking for myself, I am quite unable to see why a collar-cell cannot differentiate, especially when one remembers that an embryonic cell can become a collar-cell. If the stimulus can be provided to make a cell undergo certain changes in one direction, why should not other stimuli cause the changed cell to pass back along its former path? The collar-cell is not a highly differentiated cell, such as a metazoan ganglion or gland-cell.

(h) *Final Remarks.*

Professor Dendy has given me permission to state that he accepts my explanation that what he described in his plate 24. fig. 52, as feeding of the oocyte by nurse-cells, is really a stage in fertilization.

The question of the true nature of the sperm-carrying cell is less well established, but Professor Dendy considers that in all probability my interpretation will be found to be the correct one.

The problem of the spermatogenesis is a moot point, but I believe that few will doubt that what I have described in text-fig. 1 and Pl. **19.** figs. 5 and 5 A are the true stages in *Grantia*. Haeckel, Poléjaeff, and Dendy have failed to bring forward convincing evidence as to the spermatogenesis, and no cytologist acquainted with these questions would identify the "sperm-balls" of these workers as authentic stages in the formation of spermatozoa in any animal.

Attention is drawn to the remarkable facts which other authors and I have established with reference to sponge gametogenesis :—

1. The young oocyte bodily engulfs large cells and feeds at their expense.
2. The oocyte and ovum are both amœboid and capable of moving through the mesoglea.
3. Spermatozoa are developed in special nurse-chambers, possibly formed of mesogleal cells.
4. The spermatozoa are carried to the oocytes by special carrier-cells, which are very probably collar-cells.
5. The larva is nourished by a special nutrient chamber formed of mesogleal cells.
6. The pupal stages comprise many peculiar events, which lead to the formation of the sponge.

Probably in no other order does the gametogenesis and early development present so many extraordinary peculiarities.

This paper merely touches on a few of these peculiarities, and I hope in subsequent work further to pursue the subject.

28. SUMMARY.

Choanocyte or Collar-Cell.

1. The nuclear background contains a fairly dense basophil substance, which is either a dense linin network or a chromophil karyoplasm—more probably the latter (Pl. **19.** fig. 1).
2. The collar of the choanocyte has two thickenings, an inner and an outer; the latter one is very well marked; both thickenings are more easily seen in the partly withdrawn collar (Pl. **19.** fig. 1, B).
3. The collar consists of delicate protoplasm which is best preserved by

prolonged osmication; the collar-cell is often drawn out into two regions, an outer "neck" and an inner "base," containing all the granules and the nucleus (Pl. **19.** fig. 4); the Golgi apparatus and centrosome generally lie in the "neck," other granules in the "base."

4. Collar-cells contain three cell-elements other than the nucleus: the Golgi apparatus (and centrosome), the mitochondria, and metaplasmic store-granules.

5. The mitochondria are irregular, but fine, and lie around the nucleus (Pl. **19.** fig. 1, M, fig. 3, M.)

6. The metaplasmic or yolky store granules are much larger than the mitochondria, but lie in the same region. (Pl. **19.** figs. 1 and 4, Y).

7. The Golgi apparatus lies in the "neck" of the bottle-shaped cell, either upon the nucleus (Pl. **19.** fig. 1, A) or separately (Pl. **19.** fig. 1, B).

8. In certain definite cases the centrosome is seen to lie inside the Golgi apparatus (Pl. **19.** fig. 1, A) and the flagellum originates from the centrosome. In other cases the centrosome appeared separate (Pl. **19.** fig. 4, C?).

Oogenesis.

1. The young oocyte contains the three cytoplasmic inclusions: yolk granules, Golgi apparatus, and mitochondria (Pl. **19.** figs. 2 and 9).

2. The oocyte consists of two well-marked regions: a peripheral smooth ectoplasm and an internal frothy endoplasm, in which all the cytoplasmic granules lie (Pl. **19.** fig. 9).

3. The Golgi apparatus consists of isolated multiple elements formed of several rods arranged in angular formation, much resembling that of the mollusc oocyte (Pl. **19.** fig. 2, GAO).

4. The mitochondria are fairly large, often irregular bodies, lying in the endoplasm (Pl. **19.** fig. 9, M). In the ripe oocyte they are often abnormally large, and are never very numerous. The mitochondria constitute the "chromidia" of Jörgensen and Dendy. In their histochemical reactions they differ from chromatin.

5. Yolk-spheres are very fine and delicate, entirely filling the endoplasm and lying in the trabeculæ between the endoplasmic vacuoles. The yolk is only properly preserved by Kopsch's method. Yolk-granules are formed in and by the ground-cytoplasm, and have no connection with the mitochondria (Pl. **19.** fig. 9 etc., Y).

6. The egg is amœboid and ectoplasmic pseudopodia are common (Pl. **19.** fig. 9, ECT).

7. The full-grown oocyte is oval or elliptical in shape, as is the nucleus, but the granules and yolk are evenly disposed, and there is no sign of a definite vegetative or animal pole.

8. No organ-forming areas, or visible aggregations of cytoplasmic materials, was made out.

Spermatogenesis *.

1. The spermatozoon is probably a (flagellated) ovoid body, containing a bun-shaped nucleus. The spermatid is flagellate, so we know that the spermatozoon must be flagellated, though one was never found outside a sperm-carrying cell. In Pl. **19**. fig. 6 is drawn a sperm from a sperm-carrying cell, the tail being added from observation of spermatids. The sperm has an acrosome in front, which lies on the edge of the cell, but which is not pointed. The nucleus of the spermatozoon is bun-shaped, reticulate, and contains a nucleolus (karyosome); the mitochondrial apparatus is in the form of a bun-shaped fuchsinophile, macromitosome ("Nebenkern"), or middle-piece. The centrosome lies partly between the nucleus and macromitosome, but more in the latter than in the former (Pl. **19**. fig. 6).

2. Spermatogenesis takes place inside a definite capsule of pale, cubical, granular, non-flagellated mesogleal cells. The sperm-stages are aggregated into little patches here and there throughout the entire area of the hermaphrodite sponge; these patches lie beneath the flagellated gastral epithelium, and stain more darkly than their surroundings. Both spermatocytes and spermatids have been identified; the latter are flagellated (text-fig. 1 and Pl. **19**. fig. 5 A).

3. The number of spermatids in one patch is generally above fifty.

Fertilization (1*st Part*).

1. The ripe sperm, after having entered into the gastral cavities, is carried from the collar-epithelium to the oocyte by means of a carrier-cell. The sperm lies inside the carrier-cell, which bears its passenger to the oocyte.

2. The carrier-cell is assumed to be a modified collar-cell or choanocyte, for the following reasons:—

(*a*) There are two cases in which I have found a sperm inside a collar-cell (text-fig. 2, Pl. **20**. fig. 10).

(*b*) There are a large number of cases in which I have found a sperm inside a cell which closely resembles a collar-cell, except for absence of collar and flagellum, and which lies still within the collar-epithelium in the position drawn in text-fig. 3.

(*c*) There are about fifty cases in which I found the spermatozoon contained within a cell which always lay in the region indicated by the black dots in text-fig. 4. No sperm-carrying cells or spermatozoa were found in any part of the mesoglea or at the short sides of the egg.

(*d*) I have never found, nor has any other author figured, mesogleal amœbocytes lying near unfertilized oocytes, in the invariable position in which the sperm-carrying cell later appears—only collar-cells are found there; the gastral cavities were not found to contain sperm-carrying cells—the collar-cells alone can be the source of the sperm-carrying cells.

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* See foot-note on page 279.

3. The entry of the spermatozoon into the collar-cell does not cause the former to break up into its constituent parts.

4. The entry of the sperm into the collar-cell or choanocyte causes the latter to lose its collar and flagellum. Subsequently the nucleus of the collar-cell may lose that characteristic smooth chromophil background, and become more open and reticulate—this does not always occur. The sperm-containing choanocyte sinks below its fellows in the epithelium (text-fig. 3), passes through the basement-membrane of the choanocyte epithelium, and comes to rest on that surface of the oocyte nearest the collar-epithelium. Occasionally, the sperm-bearing cell makes a hollow in the egg, into which it fits (Pl. **20**. fig. 11).

5. The wall of the sperm-carrying cell and of the oocyte vitelline membrane come into direct contact; they become interrupted, protoplasmic continuity is established, and the spermatozoon flows passively into the egg (Pl. **20**. figs. 11, 12, 14, and 16).

6. The sperm may enter the egg frontways, backways, or sideways (Pl. **20**. figs. 11 and 12).

7. The sperm does not appear to undergo the special rotation noted in other forms.

8. The sperm-carrying cell, after the sperm has passed away, does not immediately change, for it can be found during early cleavage. Later on it becomes increasingly difficult to find this cell, and one is led to believe that it subsequently wanders away from the scene of its former activity. In one case I thought the sperm-carrying cell had begun to degenerate.

9. From the fact that the spermatozoa are always found in a circumscribed area of the flagellated cavities, just where the eggs lie, it has been concluded that this is a definite example of chemotaxis (text-fig. 4).

Fertilization (2nd Part).

10. The spermatozoon, after entry into the egg, first of all loses its cell-wall, which degenerates.

11. The acrosome next becomes chromophobe, while the edges of the sperm-cytoplasm tend to spread into the surrounding egg-cytoplasm, being for some time recognizable by its coarse stringy appearance, but later it can no longer be noticed (Pl. **20**. figs. 16 and 17).

12. The sperm nucleus now begins to grow, and other nucleoli put in an appearance (Pl. **20**. fig. 13). The nucleus becomes spherical.

13. The sperm-middle-piece or macromitosome breaks up into a cloud of fine granules, which adhere to the growing male-pronucleus like the tail of a comet (Pl. **20**. fig. 17, MAM). In a later stage these granules could not be identified.

14. Soon after the entry of the sperm, one finds that in the majority of oocytes there is a flowing towards the region of entry of many of the

mitochondrial spheres, so that the hemisphere away from the gastral layer is partly bereft of mitochondria (Pl. **20.** figs. 10 and 13).

15. The path of entry of the sperm is marked by an area formed of a chromophobe vacuolated substance, probably *intra vitam* of a liquid nature.

16. The oocyte nucleus breaks up and forms two polar bodies during these changes in the spermatozoon (Pl. **20.** fig. 13, PB), and finally the male and female pronuclei grow to the same large size (Pl. **21.** fig. 18).

Cleavage and Development.

1. During cleavage and early development the yolk and mitochondrial granules are sub-equally sorted out among the blastomeres (Pl. **21.** figs. 19, 20, 22, and 21).

2. During the histogenesis of the two main tissues of the sponge-larva (Pl. **23.** fig. 28, FC & GC), these mitochondria and yolk-grains (and probably the Golgi elements), though sorted out previously into subequal quantities between the blastomeres, later become more or less numerous, or specially modified or grouped in special regions, as the tissues develop and differentiate.

3. Such differentiation is not, so far as the granules themselves are concerned, in any way traceable to a special segregation during cleavage.

4. The fixing and staining reactions of the yolk-spheres of the egg are different from those of the amphiblastula larva, for during differentiation or histogenesis the yolk-spheres become denser and less delicate, especially in the flagellated cells. The same applies, though less well, in the case of the mitochondria.

The Amphiblastula Larva.

1. The larva is formed of three sorts of cells: anterior flagellated histocytes, posterior "granular" archeocytes, and inner amœbocytes. All these originate and differentiate from a unilaminar blastula formed of similar cells (Pl. **21.** fig. 21). For larvæ see Pl. **23.** figs. 28 and 32.

2. The larva in later stages of its formation becomes partly or wholly surrounded by a layer of squamous mesogleal (maternal) cells, which are marked by their containing peculiar irregular mitochondria. This nutrient capsule is best developed near the posterior "granular-cell" pole of the larva, and often interrupted on the flagellated hemisphere (Pl. **23.** figs. 28 and 32).

3. In many cases these maternal cells penetrate and lie among the posterior "granular cells" (Pl. **23.** fig. 28, LGC); when the larva breaks away from the sponge the nutrient capsule is left behind.

4. The histology of the three cell-elements of the larva is as follows:—

The flagellated hemisphere is formed of flagellated cells, marked especially in the live animal by the possession at their posterior or inner pole of a dense group of yolk-spheres which are pigmented (brownish). There is mixed up with these yolk-granules, but more towards the posterior or inner pole, a number of mitochondria. At the outer or anterior pole of the cell lie a group of special granules doubtfully identified as of true yolky nature. The nucleus is small, extremely basophil, and contains a karyosome. Lying on the nucleus is a distinctly marked capsular body, from which the flagellum arises ; this body is thought to be the Golgi apparatus (Pl. **23.** fig. 33).

The large centrally situated "granular cells" (GC in Pl. **23.** figs. 28 and 32) are formed of a nucleus which stains palely, and contains a coarse karyosome and a cytoplasm in which lies a number of granules, some mitochondria, others yolk, and certain others (GX in Pl. **23.** fig. 31) possibly Golgi apparatus. In most cases these large granular cells contain fewer yolk-spheres than the flagellated cells and about the same number of mitochondria.

5. The smaller inner granular amœboid cells (or mesenchyme) are apparently derived by an inward immigration from the flagellated cells, and are distinguished by the fact that they are crammed with mitochondrial granules and possess very little, if any, yolk. In *Grantia compressa* the amphiblastula, at the period drawn in Pl. **23.** fig. 28, generally contains only two or three such cells (Pl. **23.** fig. 30).

University College, London,
October 30, 1919.

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DESCRIPTION OF THE PLATES.

Explanation of Lettering.

*a*1,*a*2,*a*3=stages in passage of collar-cell into mesoglea.
AC=acrosome.
AS=archoplasmic sphere.
BM=basement-membrane of collar epithelium.
C=centrosome.
COL=collar of collar-cell.
ECT=ectoplasmic zone of oocyte or egg.
END=endoplasmic zone of oocyte.
FC=future histocytes or collar-cells of larva.
FL=flagellum.
FPN=female pronucleus.
GA=Golgi apparatus.
GAO=Golgi apparatus of oocyte.
GAM=granular (mitochondria) amœbocyte.
GC=granular cells of larva.
GCAV=gastral cavity of sponge.
GCX=future granular (and lower cells?) of larva.
GE=gastral or collar-cell epithelium.
GX=large granules possibly of Golgi nature.
IT=inner thickening of collar.
LGC=lower granular cells of larva, as distinguished from inner granular cells.
M=mitochondrium.
M&NG=mitochondria and nutrient (yolk) granules.
MAM=macromitosome ("Nebenkern") or middle-piece of sperm.
MES=mesogleal cells.
MPN=male pronucleus.
N=nucleus.
NCH=nucleus of collar-cell (choanocyte).
NK=drawn-out "neck" of collar-cell formed of hyaline protoplasm.
NSC=nurse-cells associated with spermatogenesis.
OG=outer granules of flagellated cell (possibly yolk of some sort).
OGA=oogonium (young oocyte) formed *in situ* from collar-cell.
OT=outer thickening of collar.
OTE=oocyte.
PB=polar body.
PC=first stages of metamorphosis of collar-cell into germ-cell.
PE=thickening of protoplasm on periphery of collar-cell, inside the collar.
S=sperm.
SCC=sperm-carrying cell (metamorphosed collar-cell).
SN=sperm-nucleus.
SPA=space around, forming spermatozoa or nurse-cavity.
SPT=spermatids.
VAC=vacuolated region of cytoplasm caused by entry of sperm and flow of material to the region of entry.
x=supposed remains of macromitosome (MAM).
Y=yolk-sphere or nutrient metaplasmic granule.

With regard to fixation and staining, the following abbreviations have been used:—
F.W.A.=Flemming's fluid without acetic acid; H.W.A.=Hermann's fluid without acetic

acid; K. = Kopsch; I.H. = Heidenhain's Iron Alum Hæmatoxylin; Ch.K. = Champy-Kull; Alt. = Altmann's stain.

All figures have been drawn with camera lucida by means of a $\frac{1}{18}$ semi-apochromatic oil immersion and compensating eye-pieces. Figs. 2, 3, 5 *a*, 6, 7, 8, 9, 11–22, and 29–31, and 33 were drawn with an 18 compensating eye-piece. Figs. 5 and 23–28 and 32 with an 8 compensating eye-piece. Figs. 1 and 4 were not drawn to scale. Fig. 10 was drawn with a 12 compensating eye-piece.

The Plates have been reduced, but a scale is given at the side of Plate **21**, which applies to all figs. drawn with an 18 compensating eye-piece. Scale to fig. 10 is alongside the drawing. Scale to all the figs. on Plate **22** is given at the left side, excepting to figs. 29–31 and 33, whose scale is found on the right.

While Pl. **19.** figs. 1, 4, and 9 are drawn with the camera lucida, they are a combination, of both Kopsch, Champy-Kull, and Iron Alum Hæmatoxylin preparations. The same applies to Pl. **20.** figs. 13, 14, and Pl. **21.** figs. 18, 22. Every care has been taken, however, to see that the strictest accuracy has been preserved, corresponding stages in Champy-Kull or F.W.A. and I.H. being united with those in Kopsch preparations. All the other figures are drawn from one preparation only. *In each case the arrow points to the nearest gastral cavity* (*compare* Pl. **19.** fig. 5 *to illustrate this*).

PLATE 19.

Fig. 1 A & B. Two collar-cells or choanocytes drawn and combined from two preparations, one by Kopsch's method (fig. 2), the other by chrome-osmium and Iron Hæmatoxylin. The smaller granules are mitochondria, the larger yolk-spheres (reserve granules). In fig. 1 A, the nucleus lies on the outer part of the cell, in fig. 1 B in the middle; in each the Golgi apparatus is shown at GA; in fig. 1 A the flagellum comes out of the latter, in fig. 1 B it passes through or to one side of the Golgi apparatus, and reaches to the centrosome, which lies on the nucleus. The collar in fig. 1 B is partly retracted and shows an outer (OT) and an inner thickening (IT); in fig. 1 A the collar is stretched out and the thickenings are not so marked. On the periphery of the cell, at PE, is a denser region of the protoplasm. K. and I.H.

Fig. 2. Row of choanocytes and a young oocyte by Kopsch's method.

Fig. 3. Same, fixed in Hermann-without-acetic acid and stained in Iron Hæmatoxylin.

Fig. 4. Choanocyte by Kopsch's method, to show characteristic neck to cell (NK). This consists of hyaline protoplasm. The Golgi apparatus (GA) is very clearly marked, and consists of archoplasm (AS) surrounded by a peripheral layer of darkly staining matter (GA).

Fig. 5. Part of a hermaphrodite sponge which contained ripe oocytes and ripening spermatids. The latter (SPT) lie in a special cavity (SPA), lined by non-flagellate cells (NSC) without collars. These cells are probably formed in the mesoglea. At GCAV is the gastral cavity lined by choanocytes (GE), and at OTE is the oocyte showing ectoplasmic (ECT) and endoplasmic (END) regions; this oocyte is just about to be fertilized (S). Note the tails (axial filaments) of the spermatids.

Fig. 5 A. A group of three spermatids drawn at a high power showing nucleus with karyosome, the centrosome, and the axial filament. The mitochondrial substance was washed away. Cajal.

Fig. 6. Spermatozoon drawn from an example which has passed into a collar-cell as in fig. 9, S. The tail has been added from observation of ripening spermatids, and this figure is thought to represent the ripe unchanged sperm of *Grantia compressa*. At AC is the acrosome. Ch.K. (See footnote on page 279.)

Fig. 7. Ordinary amœboid cell of the mesoglea of *Grantia*; it lies in the mesogleal fibrous tissue (MES). At M are its mitochondria. There is a distinct ectoplasm. Ch.K., I.H.

Fig. 8. An oogonium of the mesoglea; the arrows point to the nearest gastral cavities. Ch.K.

Fig. 9. Full-grown oocyte of *Grantia* with nearest accompanying choanocytes, in one of which (at S) a sperm has entered. This oocyte shows the typical endoplasmic region with the granular inclusions and the ectoplasmic part; on the left is a pseudopodium. At M the mitochondria, and at Y the yolk-granules, are evenly distributed; no animal or vegetative pole could be identified by reason of unequal distribution of the cell-granules. Ch.K., I.H., & K.

PLATE 20.

Fig. 10. Oocyte at lower magnification to preceding, showing large sperm just after entry. The cell-granules tend to approach the region of entry of the sperm.

Figs. 11 & 14. Gastral side of oocyte showing sperm-carrying cell lying upon the former; in both sperm-carrying cells the nucleus is flattened on one side owing to the pressure of the contained sperm; in fig. 11 the sperm will enter middle-piece forwards, in fig. 14 middle-piece backwards. The ectoplasm in the region of entry of the sperm is interrupted. In fig. 11 yolk is not shown. Ch.K.

Fig. 12. Sperm just entering, acrosome first. Shows protoplasmic continuity between sperm-carrying cell and oocyte. Ch.K.

Fig. 13. Later stage, polar body at PB, and female pronucleus growing (FPN). Sperm-path marked by pale chromophobe area (VAC). Note large size of mitochondria (M). Macromitosome of sperm disappeared, but may be represented by granules at *x*. Ch.K., I.H., & K.

Fig. 14. See description to fig. 11. Ch.K., I.H., & K.

Fig. 15. Flattened sperm-bearing cell, which was compressed by egg, and so looks abnormally large. Its nucleus is of the open type. Ch.K.

Fig. 16. Sperm just after entry; its cell-wall has disappeared, macromitosome still complete, and sperm-cytoplasm furred at edges but still distinguishable from egg-cytoplasm by its greater chromophility and stringiness. Acrosome pale. Nucleus nearly spherical and has grown. Sperm-carrying cell at SCC, with open nucleus.

Fig. 16. Stage in fertilization after that in fig. 12. The sperm cell-wall has disappeared and its stringy cytoplasm is still distinct from that of the egg. The acrosome (AC) is becoming faint. Ch.K.

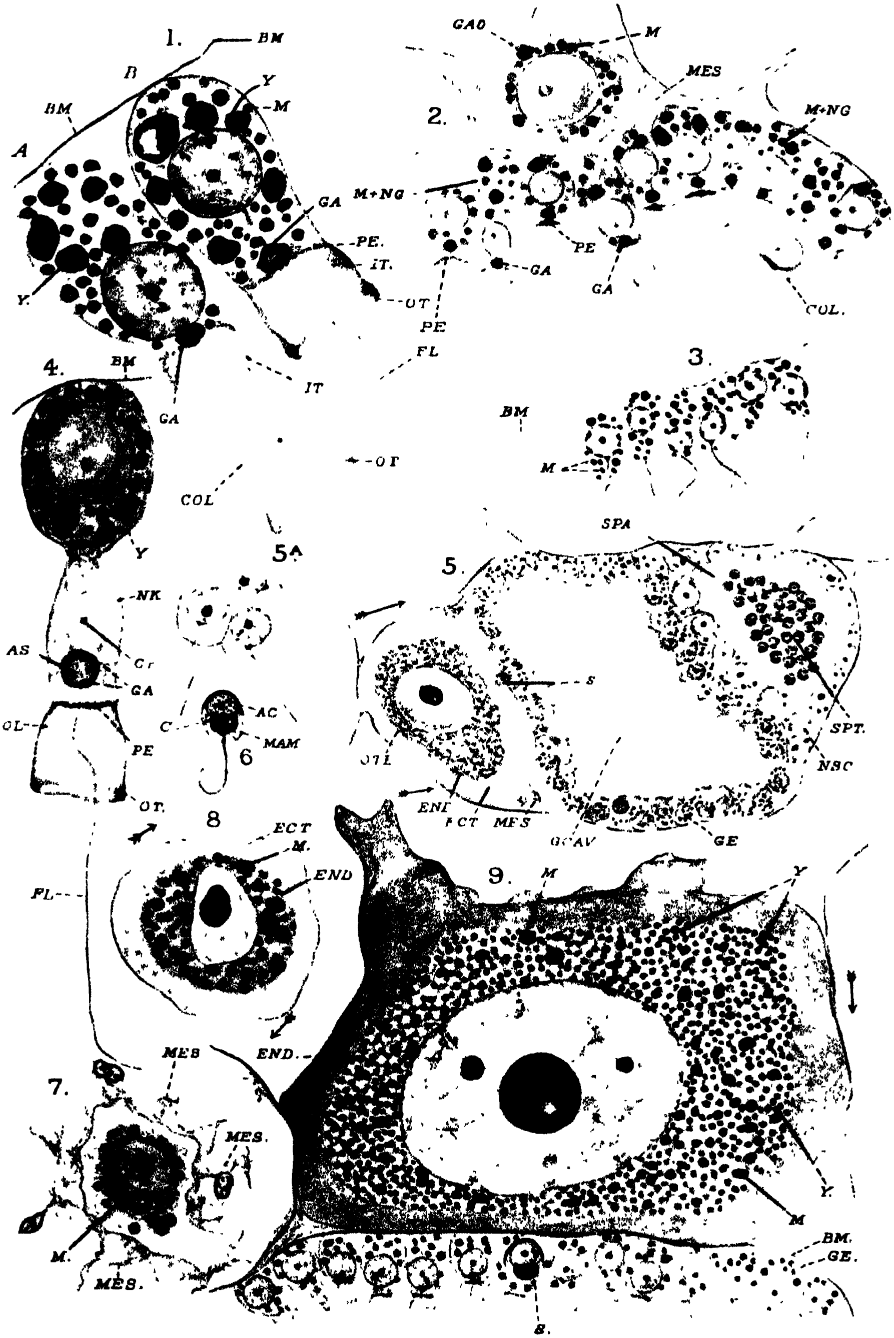
Fig. 17. Later stage just after breaking up of sperm middle-piece or macromitosome (MAM). This preparation was fixed by Champy-Kull and stained by Heidenhain's Iron Alum Hæmatoxylin. Note that nuclei of sperm-carrying cell (SCC) and those of choanocytes (NCH) stain alike. Ch.K., I.H.

PLATE 21.

Fig. 18. The two pronuclei side by side prior to last stage of fertilization. Note even disposal of inclusions (M & Y). The sperm-carrying cell (SCC) is degenerating in this case. Yolk added from another preparation at a similar stage. Ch.K. & K.

Fig. 19. Two-cell stage, showing even disposal of mitochondria. Upper blastomere not cut across middle. Ectoplasm evenly divided. Ch.K., I.H.

Fig. 20. Four-cell stage, showing continued subequal distribution of the mitochondria and of ectoplasm. H.W.A., I.H.



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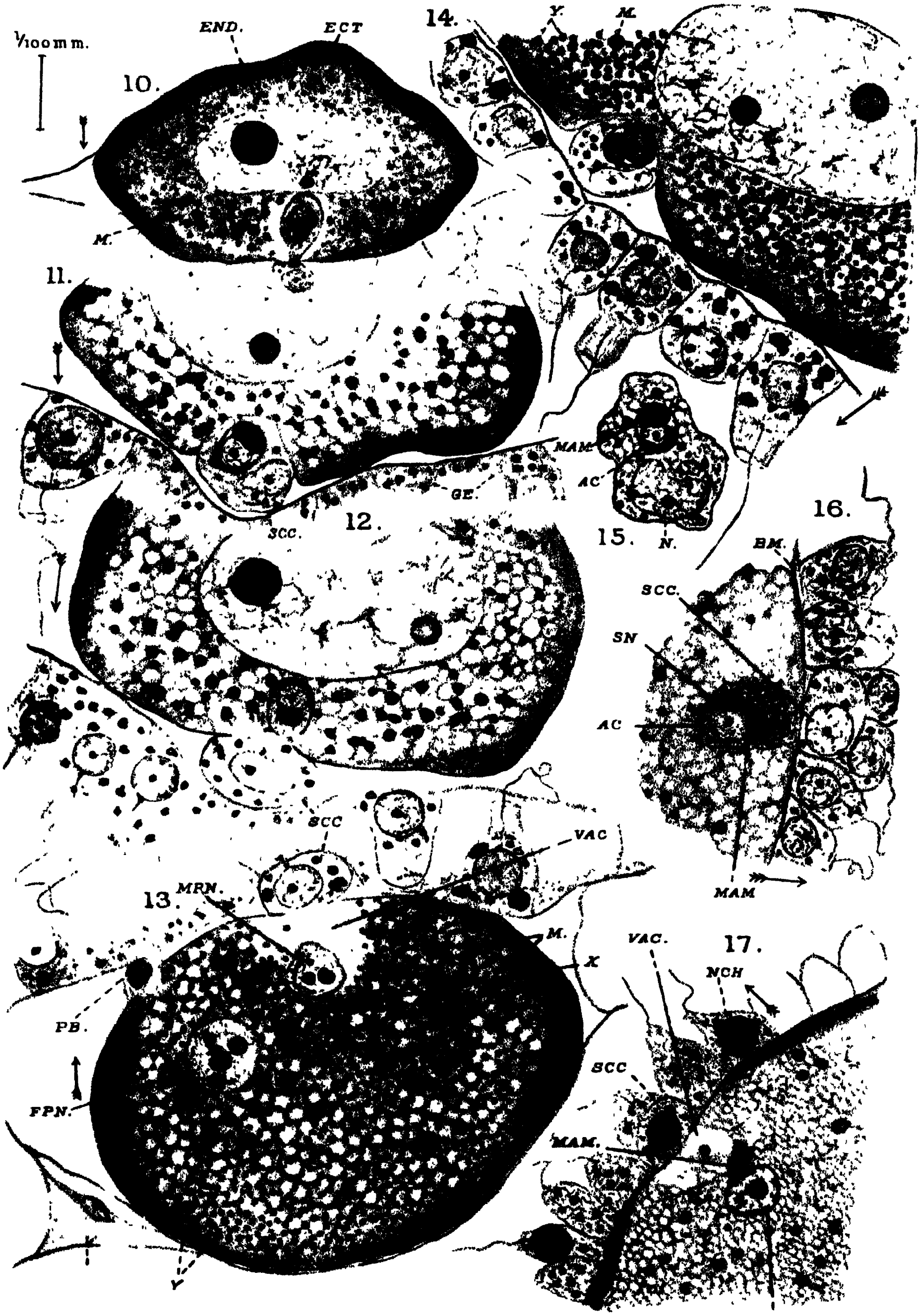
GRANTIA (SYCON) COMPRESSA.



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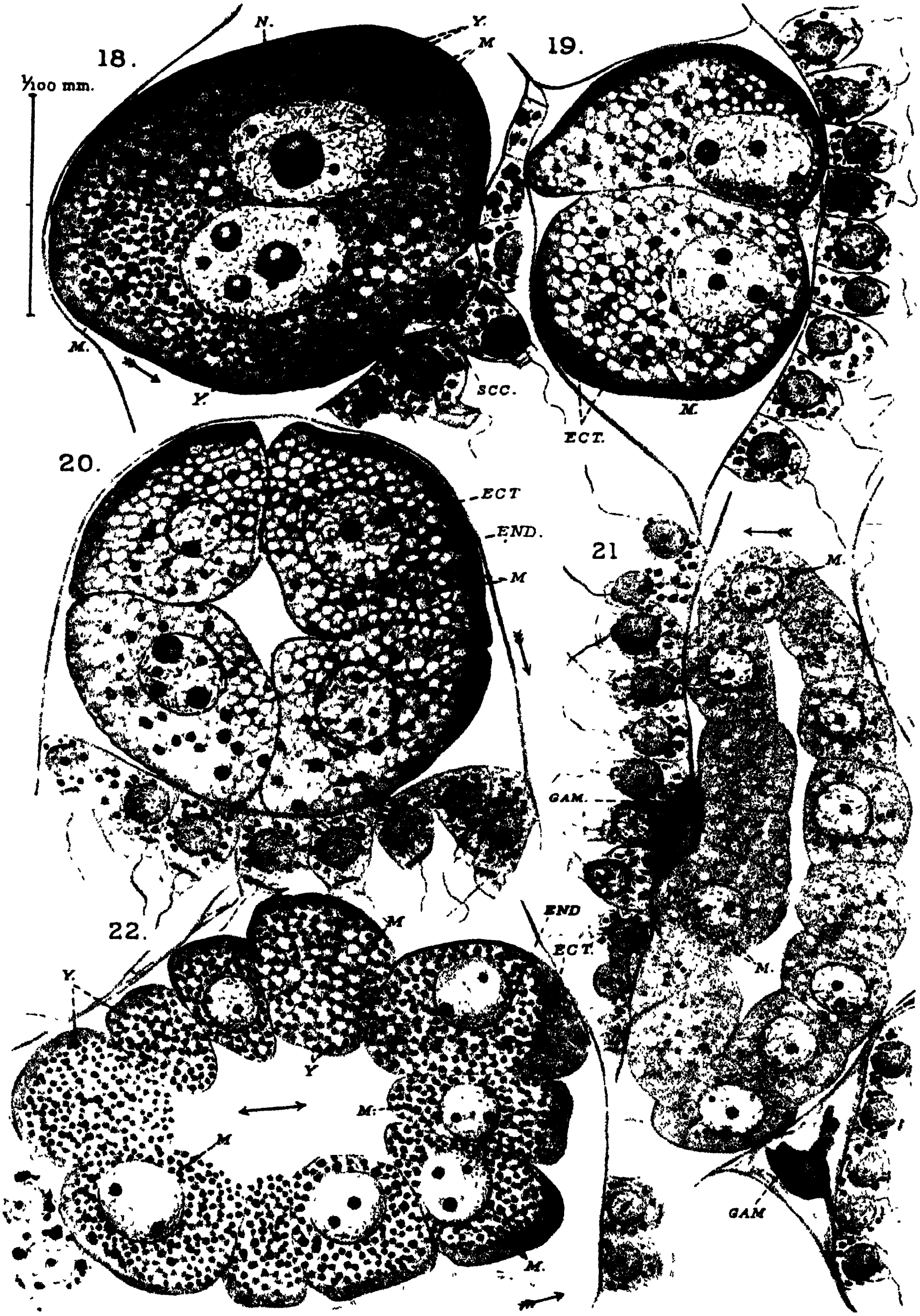

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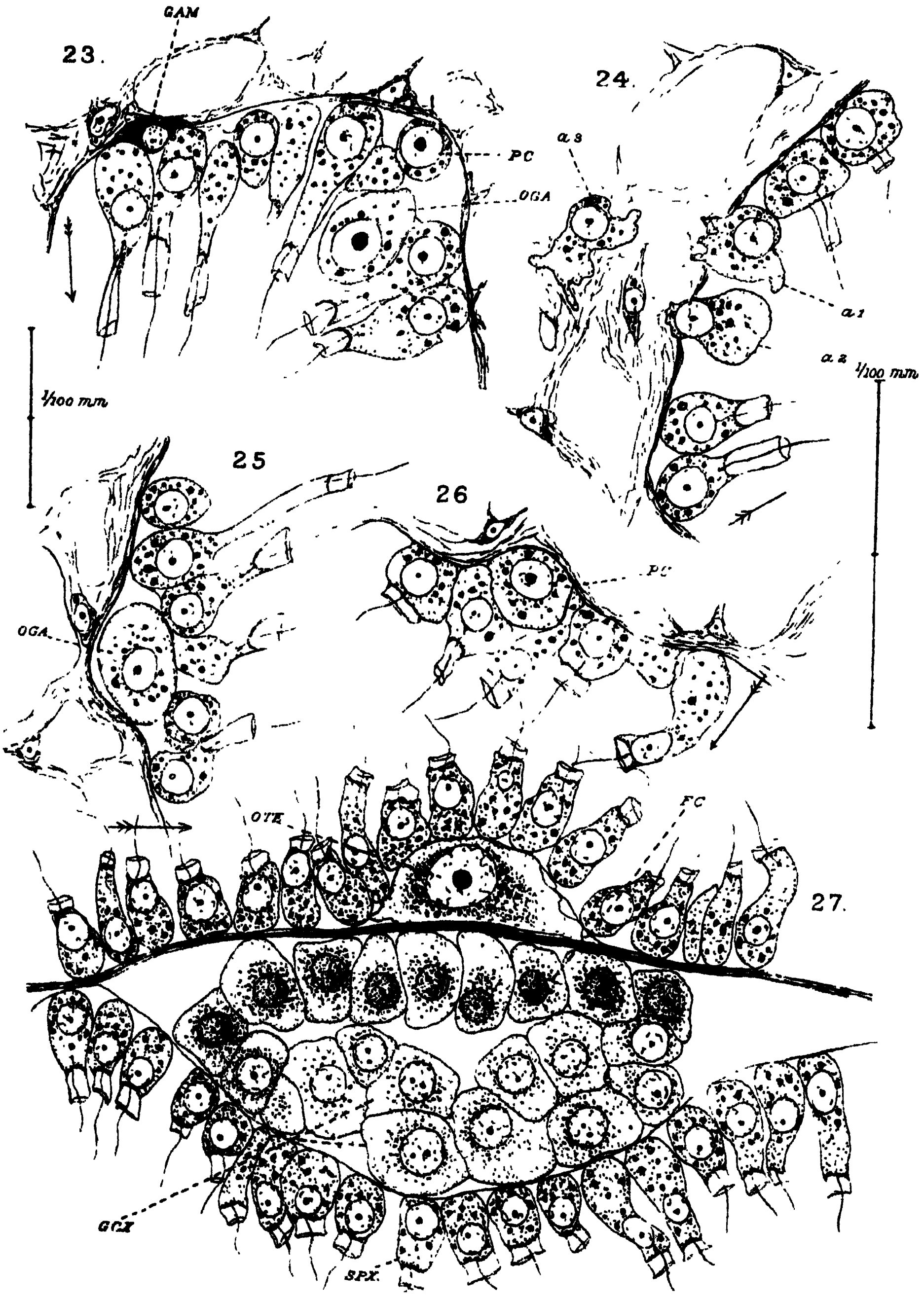

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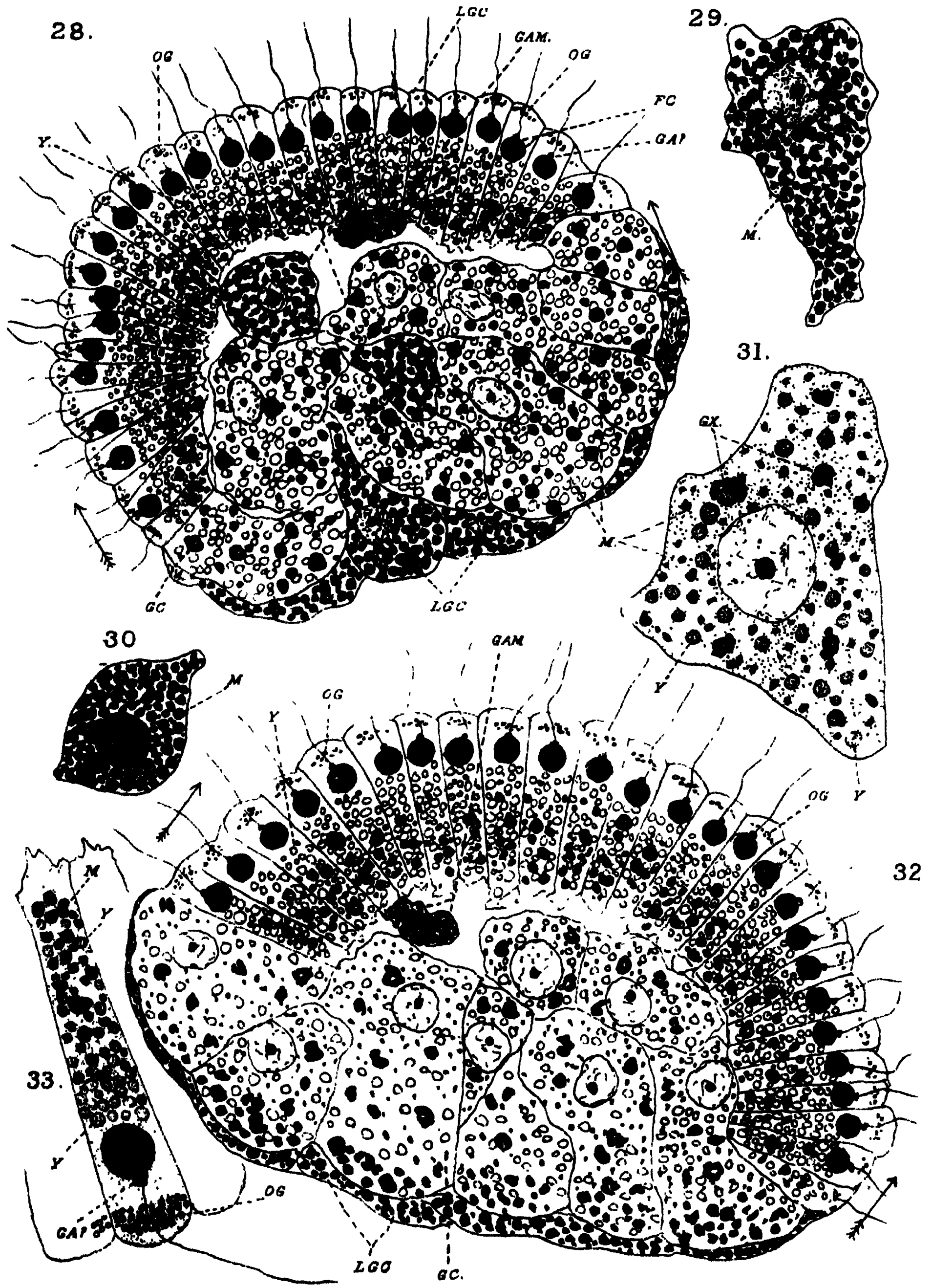

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GRANTIA (SYCON) COMPRESSA.

Fig. 21. Blastula just before differentiation of flagellated hemisphere (see Pl. **22**. fig. 27). The fine mitochondria, still visible but staining less well, lie around the nuclei. The yolk is not shown. At GAM is a granular amœboid cell. Judging from the contour of this blastula, the future flagellated hemisphere will differentiate on the right, and away from the nearest collar-cell. Ch.K., I.H.

Fig. 22. Younger blastula showing even segregation in each blastomere of yolk-spheres and mitochondria. The ectoplasm is slightly larger in quantity on the right than on the left. The yolk-spheres have been added from another preparation prepared by Kopsch's method. Ch.K., I.H., & K.

Plate **22**.

Figs. 23, 25, & 26. Parts of flagellated gastral epithelium, showing at PC and OGA two stages in metamorphosis of collar-cell into oogonium. Ch.K., I.H.

Fig. 24. Part of flagellated gastral epithelium showing immigration inwards of collar-cells, *a* 1, *a* 2, & *a* 3, into the mesoglea. Ch.K., I.H.

Fig. 27. Differentiating amphiblastula, showing future flagellated cells (FC) and future lower and granular cells (GCX). At OTE is a young oocyte in growth-stage.

Plate **23**.

Figs. 28 & 32. Two amphiblastula larvæ, for description of which see page 266. Ch.K., I.H.. and Ch.K., Alt.

Fig. 29. Maternal nutrient capsule-cell (LGC in fig. 28), showing irregular and numerous mitochondria (M). Ch.K., I.H.

Fig. 30. Inner amœboid granular cell (GIIM in fig. 28) showing dense numerous mitochondria.

Fig. 31. Granular cell (GC in fig. 28) showing scattered yolk-spheres (Y), mitochondria (M), and what are possibly Golgi elements at GX. Ch.K., I.H.

Fig. 32. (See legend to fig. 28.)

Fig. 33. Flagellated cell or histocyte showing four cytoplasmic elements. Mitochondria (M), yolk (Y), Golgi apparatus (GA ?), and outer "yolk" granules at OG.

The Fragrance of Calcinean Sponges and the Spermatozoa of *Guancha* and *Sycon*. By G. P. Bidder, Sc.D., F.L.S.

(Plate **24**.)

[Read 6th May, 1920.]

In collecting the characters which indicate that two completely separate groups of sponges have spicules of calcite, I stated that in Calcinea "most species show varieties which are coral-red and sulphur-yellow," while in Calcaronea "the sponges never show a coral-red or sulphur-yellow colour" (1898*c*, p. 73)*. I would now suggest the possible additional group-characteristic of odour.

The scent from freshly-gathered Clathrinidæ is very noticeable. To me it is stimulating and pleasurable, it has always recalled the ozone from an electric discharge; the suggestion is aromatic, it is perhaps possible to find a faint association with garlic. (The efflorescence of dry-rot—curiously like *Guancha coriacea* or *Ascaltis reticulum* in appearance—has a similar smell.)

The odour of *Leucandra aspera*, *Sycon raphanus*, and *Grantia compressa*, like their colour, is much less noticeable than that of the Clathrinidæ. Probably the cause of the difference in odour is to be sought in the cause of the difference in colour, that is, in the excretory granules of the cells of the skin, a great part of which is soluble in distilled water, alcohol, etc. (1892 *b*, p. 482). (See Note C, *infra*, p. 317.)

I suggest that the advantage of the scenting of the water near the sponges is the production of chemiotaxis in spermatozoa from sponges of the same species. The water of the sea must contain the spermatozoa of all the phyla which inhabit it, and these will be borne in with other suspended nutritious particles by the afferent currents of the sponge. But these currents are very slow—in *Leucandra aspera*, from my measurements, about 30 μ a second at a distance of 2·5 cm. from the sponge surface,—and directed progression by spermatozoa of the species would therefore in still water importantly increase the proportion of them which enter the sponge. Church gives data for velocities of antherozoids ranging from 100 μ to 300 μ a second (1919, p. 5).

Are there flagellate spermatozoa in Calcinea? Poléjaeff (1882) described them in Calcaronea, but I have not seen the pulsellum-tailed spermatozoa which he observed. Figs. 1 and 2, Pl. **24**, show a free organism in a live section of *S. raphanus* tropus *aquariensis*, which may or may not have belonged to the sponge; the tail was stiff*. Figs. 4, 5, and 6 represent the emergence from [or entrance into] gonocytes in the cloacal wall of *S. raphanus aquariensis* of curious spherical cells with protruding button-like nuclei, which I call "dolly-cells," from the shape of a washerwoman's "dolly" of blue. These can be seen in some preparations in great numbers, and I suppose them (1892 *b*, p. 479, footnote) to be spermatozoa in the antecedent [or subsequent] stage to figs. 1 and 2. It is difficult to think of any alternative explanation; the contents of the gonocyte-like cells from which they emerge are spherules each with a staining-spot (fig. 4), undoubtedly not falciform, so that if the "dolly-cells" are parasitic they are certainly not Gregarines [see Postscript, p. 302].

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* For references to works quoted in this paper see p. 325.

The organisms in the chambers of *Grantia compressa* which I described as Algæ (1895, p. 31), Dendy (1914) has rediscovered as sperm-morulæ; and the objects which I identified as fæces from the collar-cells (1895, p. 18, fig. 13) he conjectures to be clumps of spermatozoon-heads (1914, fig. 93); but these new interpretations seem improbable †, and we are left to rely on Poléjaeff's observations (cf. infra, "*Syncrypta spongiarum*," p. 305, and Note D, p. 319).

For the Calcinea, Vosmaer (1887, p. 412) observed a sperm-ball in an Ascon, and I have sketched similar structures (see next paper) in *Clathrina clathrus*; but the objects drawn by me might have been an alga, like that observed by me and by Dendy in *Grantia compressa*. They are closely the same size as the "morulæ" drawn by Dendy, and the following observation is against their being spermatoblastic.

In the Calcinean *Guancha coriacea* tropus *primordialis*, I was fortunate enough to observe, pouring out in a cloud from one part only of the sponge-wall, a number of similar objects (Pl. **24.** fig. 7) which are difficult to interpret except as spermatozoa. Unfortunately the preparation was in iodine and sea-water, so that it is impossible to say what was the mobility of the organisms, but their appearance suggests that they are more wriggling than swimming organisms ‡. Reference to Minchin's figures and description (1897, p. 499, figs. 17, 19, and especially 41) shows identity of shape and size between the individuals of this erupt cloud and his "minute wandering cells" in the substance of the sponge-wall. He concluded that these remarkable little cells, sometimes spherical but more often elongated, arise by the repeated division of "clear amœbocytes." His observation also was on *Guancha* (*Clathrina*) *coriacea*. (Note A, *infra*, p. 315.)

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* These two figures are drawn from the same object. Fig. 3 is sketched from a smaller stiff-tailed organism found free in the flagellate chamber on another occasion.

† Dendy's drawings, as always, convince anyone who knows the material of their absolute fidelity. I feel no doubt from his figs. 83 and 84 that his collar-cells actually fed on the alga which I was unable to follow further than the finding single monads inside the collars. He will be interested to note in my paper of 1895 that I recorded the four-celled stage of the alga which he (p. 364) found unaccountably absent; it was without covering-cell, as are his figs. 86, 88, 89, 90, 91; the four deeply-stained spherules lay imbedded in a sphere of transparent substance, rather more plentiful, proportionately, to the spherules than in Dendy's fig. 89. Fig. 84 closely resembles a sketch I have of a collar-cell which has ingested a large starch-grain.

‡ [It is of course possible that they develop a flagellum after extrusion.]

Ever since 1887 it has been an unsolved puzzle to me why excretory granules should be localised about the afferent pores, through which the whole supply comes on which the sponge's life is based. Minchin points out this difficulty (1897, p. 527) as applying to the pore-cells, though not to the oscular porocytes and apical-ray cells. But through the afferent pores, besides oxygen and food, must enter what is (on ordinary assumptions) equally important for the survival of the species, namely spermatozoa. I suggest that the odoriferous nature of the excretion of the porocytes attracts the spermatozoa of the species which fall on the surface of the sponge, so that they make their way to the pores themselves and enter through their lumen into the flagellate cavity, and that this is the advantage of the extraordinary position of these excretory cells. It will be remembered that similar cells are also aggregated at the other opening into the flagellate cavity, on what I called in *Ascaltis cerebrum* (1891, p. 3) "the granular lip" and Minchin (1897, p. 495) "the oscular rim." (Note B, *infra*, p. 316.) The employment of an excretion to serve a useful purpose gives explanation of the origin of many new organs throughout the animal kingdom, and I have elsewhere (1892 *b* and *d*) suggested that the skeleton of the horny sponges has its origin in the same granules of these excretory cells*. The utilisation of the odoriferous properties of an excretion, both to repel and to attract, are well known in higher animals.

In regard to the fainter smell of the Calcaronea, it will be remembered that in this group, even in *Leucosolenia*, "the pylocyte is annular and generally lies at the bottom of a funnel-shaped depression or afferent canal" (1898 *c*, p. 73). Minchin (1908, p. 323) declined to see any difference in shape between the pylocytes of *Leucosolenia* and *Clathrina*, though his drawings illustrate it admirably ; but he confirmed the funnel-shaped depression in the former. This, and the commonly rougher surface of *Leucosolenia*, suggest the possibility that Calcaronea have free-swimming spermatozoa, and Calcinea have amœbuloid spermatozoa, and that the pylocytes which lead from the funnels of *Leucosolenia* or the deep afferent canals of *Sycon* and *Leucandra* are not noticeably granuliferous, because the spermatozoa of these genera remain swimming and do not creep. If this be true, it is only advantageous for the spermatozoa of Calcaronea to be attracted by the granules of the external epithelium within the zone of the currents entering the dermal pores, and once they are in this zone, it is desirable by fur of spicules and by inpouching of afferent canals to shelter the still swimming visitor from the chance surge of a current over the surface. On the other hand, it is possible that the amœbuliform characters of Calcinean spermatozoa, in so far as it is general, has limited the modifications of Canal-System in this group to those which facilitate entrance to a "minute wandering cell" fallen on the outer surface and creeping towards an odoriferous pore*.

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* Cotte (1903, p. 562) opposes this view very strongly, maintaining that spongin is a molecule of high energy. But whatever energy can be proved to have gone into the spongin molecule is in a completely unavailable form, for there are few more stable substances known.

Whether or not there be this difference between the male elements of the two groups, I venture to propose for serious consideration that in sexual sponges the excreted granules of the external surface and pore-cells have an important function in inducing chemiotaxis in the spermatozoa from other individuals of the species. This would be useless to sponges in a tideway, which must take their chance of extraneous fertilisation, but live in the best circumstances for nutrition and asexual growth. It would be of the utmost advantage to a solitary sponge in a deep cave of still water, where unfavourable conditions make the stimulation of a foreign gamete most desirable.

It would be strange if, in all the hundreds and thousands of species recognised by some modern authors, the ova of every sponge should refuse absolutely to unite with the spermatozoa from a sponge, the size of whose microscleres proved that his place is in a different paragraph of the page. I am not aware of any evidence whatsoever as to the limits or extent of crossing in sponges. *A priori*, hybridisation must play a great part in the characters we laboriously tabulate.

It is strange in any case to consider that the selective power of a spermatozoon, adrift in the North Sea, must often be as highly developed as that of a Red Admiral butterfly. Somewhere in that infinitesimal body we must picture the mechanism for this reflex, as well as the heritages to be transmitted to every part of its giant offspring, the zygote.

POSTSCRIPT. (September 1920.)

Spermatozoa of *Sycon raphanus* and fertilisation of the ovum.

Professor Dendy and Mr. Gatenby each suggested to me that, if the dolly-cells are spermatozoa, my drawings may represent their entrance into the gonocytes instead of their exit from them.

This suggestion I now accept, as also that of Mr. Gatenby, that the stained

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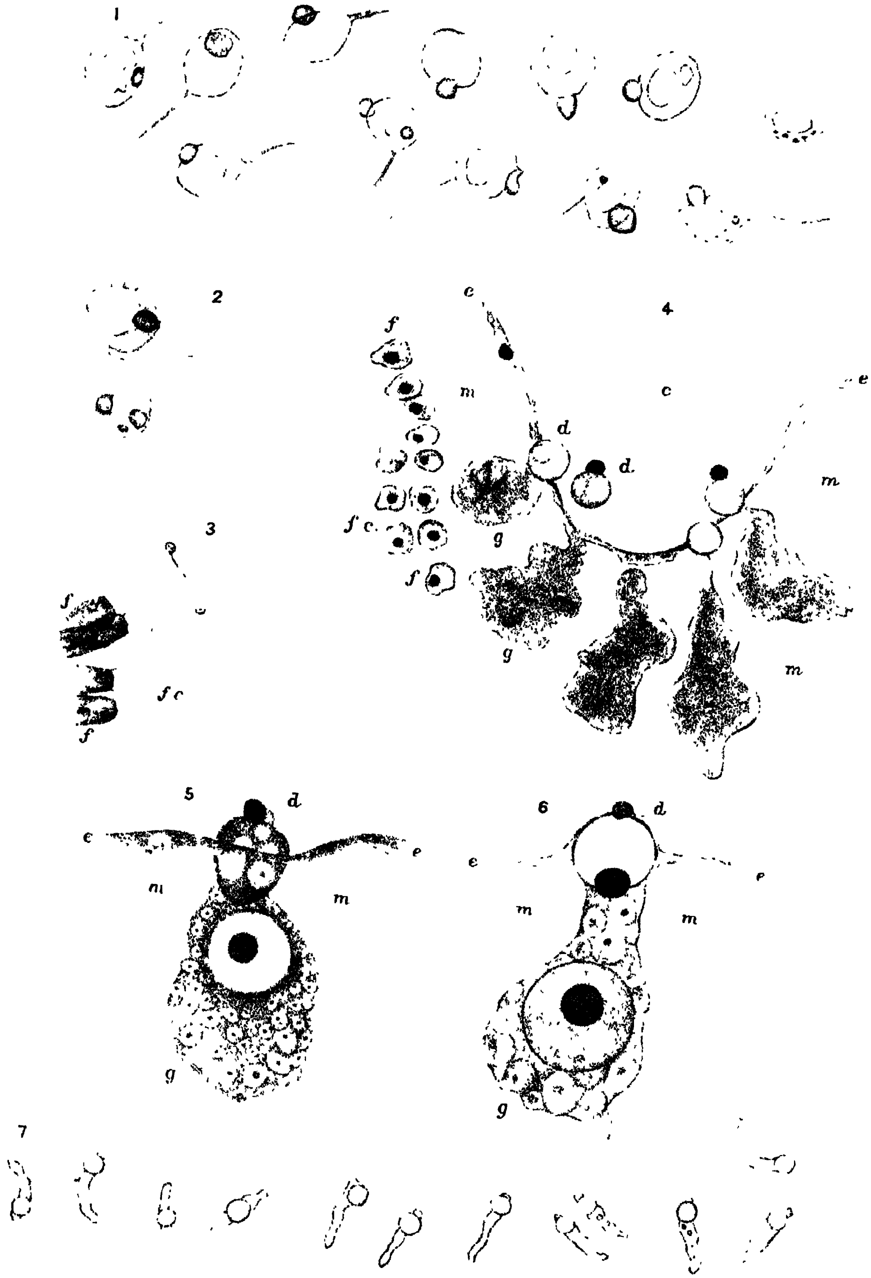
* Since this paper was read, Professor Dendy has kindly shown me the collar-cells of *Leucosolenia stolonifer*, Dendy (1891), and I have come to the conclusion that this most interesting species is an aberrant Calcinean (see 1913 *b*, p. 718). It has assumed, however, not only the outward form of *Leucosolenia*, but also the afferent funnels; therefore, if my view of its position be correct, it bears evidence against the above suggestion, and in favour of the advantage of the funnels being a hydro-mechanic advantage.

Bidder

Journ. Linn. Soc. Zool. Vol. XXXIV Pl. 24.



P. Bidder. del

Cambridge University Press

SPERMATOZOA IN SPONGES

spots within the spherules of the gonocytes are probably artefact. In some cases the spherules are indistinguishable except in number from those in the smaller unripe ova underlying the collar-cells, the spherules which I have shown (1895, p. 30; 1892 *b*, p. 477, fig. 4) to be the basal spherules of the collar-cells, withdrawn through the pseudopodia of the ovum for its sustenance (*cf.* Dendy, 1893, pp. 221, 222, fig. 50; 1914, pp. 328, 344, fig. 48). The subcloacal gonocytes (gland-cells of Dendy, 1891, fig. 26) are ova in the process of being fertilised through a micropylar pseudopodium perforating the pinacocytal epithelium (*cf.* Dendy, 1891, figs. 36, 37; 1914, p. 325). I have added figs. 5 and 6 (Pl **24**) to show the structures more clearly, but must postpone more detailed description and discussion to another paper. The difference is very startling from the fertilisation under the collar-cells of *Grantia compressa* through the intervention of a nurse-cell, as described by Mr. Gatenby and accepted by Professor Dendy at the Linnean Society (Dec. 11, 1919), and implies an unexpected genealogical separation.

The organism of figs. 1 & 2 (Pl. **24**) was measured 6·7 μ greatest × 4·6 μ smallest diameter, button 2·2 μ × 1·6 μ, tail 6 μ. It would therefore be about one-third the volume of the dolly-cell, which is 8 μ to 1[illegible] μ in diameter, with spherical button-nucleus 2·4 μ to 3·6 μ. The difference is large, but not beyond the possibility of differing nutrition. In each case the cell contains one or more large clear bodies, which Mr. Gatenby points out to me would correspond to mitochondria or middle-bodies, if these are spermatozoa—for the present I will give them the non-committal name of "grains." These grains and the button-nucleus appear to me to identify the [illegible]y-cells with the organisms of figs. 1 & 2. Fig. 3 I have added merely [illegible] record of fact, for those who have reason to believe in an altogether si[illegible] spermatozoon; though the tail was 8·0 μ long the body was only 1 [illegible]meter, or $\frac{1}{300}$ the bulk of a dolly-cell. [Identity of fig. 1 and dolly pro[illegible] 25.]

The stained object in the ovum (under the nurse-cell) of Den[illegible] 52 (1914), which, as I understood Professor Dendy to state on [illegible] now considers to be the male pronucleus, measures 2·4 μ × 1·1 μ, [illegible] fairly reconcilable with those of the button-nucleus alike of figs [illegible] of the dolly-cells. (The latter show often a second nucleus, with s[illegible]

I sh[illegible] of

EXPLANATION OF PLATE 24.

c=cloaca. *d*=dolly-cell. *e*=cloacal epithelium (pinacocytes). *f*=[illegible] (choanocytes). *f.c.*=cavity of flagellate chamber. *g*=gonocyte. *m*=mesoglœ[illegible]

The observations were on Naples sponges; the time of year is given at which the sponge was taken.

Fig. 1. (× about 1800.) March 24. Sketches in different positions of an organism fo[illegible] in a living section of *Syan raphanus* t. *aquariensis* in bismarck brown. No p[illegible] of this organism was stained by the brown. The stiff tail was about $\frac{1}{3}$ μ thic[illegible] being noted as twice the thickness of the flagella of the collar-cells.

Fig. 2. The same, sketched with a higher eye-piece.

*Fig. 3. (× about 1000.) End of March or early April. A similar stiff-tailed organism with smaller body, in another living preparation of the same species and trope.

Fig. 4. (× about 500.) Jan. 20. Section through part of the cloacal epithelium (*e.e.*) of *S. raphanus* t. *aquariensis*, killed in iodine, overstained in borax-carmine. Five gonocytes are shown (*g.g.*) and four "dolly-cells" (*d.d.*). At (*c.c.*) the section cuts the wall of a flagellate chamber. [A dolly with stiff tail since observed.]

*Fig. 5. (× about 1300.) Similar preparation killed in osmic acid, stained with aqueous methyl-green. The gonocyte shows a 'germinal vesicle' with 'germinal spot,' and contains some scores of spherules of varying size stained only in spots at their centres. The spherical cell with a knob ("dolly" from its likeness to a washerwoman's dolly of "blue") is emerging from [or entering] the gonocyte, and is half-way through the epithelial cell. The linear dimensions of the dolly and its knob are about ¾ those of the knobbed body in fig. 1. January.

*Fig. 6. (× about 1400.) Another gonocyte and dolly-cell stained with hæmatoxylin and methyl-green. Jan. 24.

Fig. 7. (× about 2200.) Jan. 13. Spermatozoa ("minute wandering-cells" of Minchin, "cercids" of N[illegible], *infra*, p. 315) of *Guancha coriacea* t. *primordialis*. Sketched from a preparation of iodine in sea-water, the granules (shown in two of the outlines) were yellow with the iodine. No spermatozoa were found in the preparation except where this cloud poured out.

[* These figures were added since the paper was read. See Postscript, p. 303.]

Syncrypta spongiarum, nova [*]. By G. P. Bidder, Sc.D., F.L.S.

(With Text-figures.)

[Read 6th May, 1920.]

In discussing the natural food of *Grantia compressa* (1895 [†], p. 31, *cf. ante*, p. 300), I wrote:—"In another specimen there are lying freely in the chambers several specimens of what appears to be an alga, one sphere of four cells, one probably of sixteen; also lying inside the collars of different collar-cells are several isolated spheres, of about the same size as the individual cells of the larger spheres and similarly stained." My rough MS. sketch of the sphere inside the collar (fig. E) when scaled by the dimensions of the collar-cell gives the diameter of the "isolated sphere" as 1·5 μ. The "sphere of four cells" (fig. A), assuming that each "cell" is 1·5 μ, has an external diameter of 7 μ. (See Text-figures, p. 308.)

Our knowledge of this organism (but under the title of sperm-morulæ) has been greatly increased by Dendy's beautiful drawings (1914, pl. 26). Mr. Gatenby's paper, read at the Linnean Society on December 11th, 1919, gave a totally different account of the spermatozoa in *Grantia*, which in the subsequent discussion was accepted by Professor Dendy; we may therefore consider the explanation of the organisms as sperm-morulæ to be withdrawn. Their identity with the objects seen by me in 1895 is shown by their situation, their binary multiplication and coherence, and their dimensions. The external diameters of the eight-celled stages of Dendy's fig. 83 and fig. 86 are 6·4 and 7·0 μ respectively, the diameters of the spherules composing them being 2·1 and 2·4 μ; while the diameter of the spherules in fig. 90 (16 cells) is 1·3 μ, and the external diameter of the 16-celled stage in fig. 92 reaches 10 μ. The sub-conical elements in his fig. 89, each bearing two spots (these are shown in four out of the six monads, see fig. H, *infra*, p. 308), are extremely like the published figures of Flagellata, and there seems no reason for any further hesitation in assigning the organism to this group. I understand from botanical friends that I shall not find in the literature a specific name for this organism, and that of *spongiarum* seems to suit the circumstances.

Since sending in this manuscript, I have observed at Plymouth that the colour of the spherules in the fresh state is golden-brown; the organism is therefore to be assigned to the Chrysomonadineæ, of which *Syncrypta* appears to be the genus whose colony and monad agree most in form with that observed, and this genus also shows a paired spot. In the new species the monads are separated by interstitial jelly as in *Uroglenopsis*, but the shape and symmetry of the individuals are as in *Syncrypta*; in *Syncrypta* also the 16-celled stage alone is figured by authors, whereas *Uroglenopsis* is shown with 64 cells or upwards. The linear dimensions of *spongiarum* are one-fourth those of *Syncrypta volvox*, and the outer coating of jelly is less; both these characters may be associated with the marine habitat. The small size precludes a statement as to presence or absence of fine needles in the jelly. I observed five 16-celled spheres in living collar-cells of *Sycon ciliatum*, and an 8-celled sphere in a flagellate chamber of *Grantia compressa*, all of diameter $3\frac{1}{2}\,\mu$ to $4\,\mu$; the constituent monads appeared to be uniformly brown spherules or polyhedra, smaller and more separated than in the stained preparations. Possibly only the chromatophores were visible.

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[*] Coloniæ globosæ, 3–12 μ diam. extern., e cellulis 4–8–16 aureo-brunneis in gummi communi immersis compositæ, interdum cellulæ solitariæ, 0·5–3 μ diam., punctis (ocellis dictis) binis et pyrenoideo magno instructæ.

Hab. in *Grantiæ compressæ* loculis flagellatis in portu "Plymouth," mensibus Dec., Jan., Apr. (et Jul. ?). In mari mediterraneo coloniæ etiam e cellulis 32 compositæ obveniunt.

[†] For references to works quoted in this paper, see p. 325.

Neither Dendy nor I have observed at Plymouth multiplication beyond 16 cells, Dendy's fig. 93 being identical with my fig. 13 *a*, of which I wrote:—"As noticed also in other sponges there are in the chambers large masses containing hundreds of transparent globules (fig. 13 *a*) laden with small detritus. While their individual size and appearance strongly suggests ejecta from the cells (*cf.* figs. 4 & 10), their large aggregate mass makes this supposition difficult without stronger evidence" (1895, p. 42). This detritus was observed in enormously greater quantities than the comparatively rare spheres of *Syncrypta* in sponges of the same date, and even if my explanation of it as cell-fæces were incorrect, it cannot be supposed to be derivative from the 4-, 8-, 16-cell stages. (Note D, p. 319.)

I propose, therefore, that the organism be assigned to the genus *Syncrypta* until an expert removes it, and put forward the following brief diagnosis:—

Syncrypta spongiarum, nova.—Spheres of 4, 8, and 16 golden-brown cells, and isolated monads, found in the flagellate chambers of *Grantia compressa* at Plymouth; external diameter of sphere 3 to $12\,\mu$. Diameter of monad $\frac{1}{2}$ to $3\,\mu$; it has a pair of "eyespots" and a large pyrenoid. The amount of inter-cellular jelly is considerable. In the Mediterranean, 32-cell stages also occur. Observed in December, January, April, and (?) July.

Dendy's fig. 82 and fig. 85 suggest the correctness of my conjecture as to the collar-cells feeding on the *Syncrypta* [which the observations recorded above have since verified on the living sponge]*; it is possible that *Syncrypta* may in some circumstances survive the process and propagate itself in the tissues of the sponge.

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* [It has become evident also that the brown "spherical dotted globule" of fig. 1, C, *infra*, p. 318, was an ingested *Syncrypta* sphere.]

In Urban's interesting paper (1910 *c*, p. 42) he describes red algæ living symbiotically in *Clathrina* at Naples *. In the mesoglœa he finds round red cells, 7 μ in diameter, giving rise by binary fission to ellipsoid cells 5 μ by 4 μ, which become separate spherical cells like the parent. After solution of the red pigment by distilled water, the cells are green.

It appears possible that the "Spermaklumpen" drawn by Vosmaer (1887, pl. 29) may be a further stage in the life-history of these cells of Urban. Scaling Vosmaer's fig. 4 roughly from the collar-cells, the diameter of his sphere is about 14 μ, or rather less if we allow for preservation in absolute alcohol †. As briefly mentioned (*ante*, p. 300), I observed a number of similar bodies in *Clathrina clathrus* at Naples (Jan. 3rd). Examined fresh under the microscope in hæmatoxylin, they stained strongly and readily before any of the other tissues; a sphere of about 32 cells was drawn (fig. D) ‡ as well as one which may have been the 16-cell stage (fig. C). In the latter the external diameter was measured to be 11 μ and the diameter of the stained spherules 1·7 μ; in the former the external diameter was 8 μ and the diameter of the spherules 1·2 μ. It will be seen that whether or not these resulted from Urban's symbiont, they, as well as Vosmaer's sperm-ball, show no difference from the *Syncrypta spongiarum* of *G. compressa*; and Vosmaer's observation (*l. c.* fig. 5), that a sphere of presumably 16 cells was enclosed in the tissues of the sponge, suggests that they are derived from the multiplication of cells in the mesoglœa, such as is described by Urban.

"Yellow bodies" were found by Dendy in his *Leucosolenia gardineri*—a clathrinid from 10 to 14 fathoms depth in the Chagos Archipelago and "closely related to .... *Leucosolenia* (*Clathrina*) *coriacea*" (1913, p. 5). He writes (p. 6):—"The idea that the yellow bodies may be symbiotic algæ also naturally suggests itself, but their chemical reactions and the fact that they contain no nuclei appear to me fatal to this view." It is remarkable, however, that the size of these yellow bodies ("·004 to ·006 mm. in diameter," p. 4) is that of the bodies identified as symbiotic algæ by Urban, who also figures them as uniformly punctated circles in his diagram of a section;

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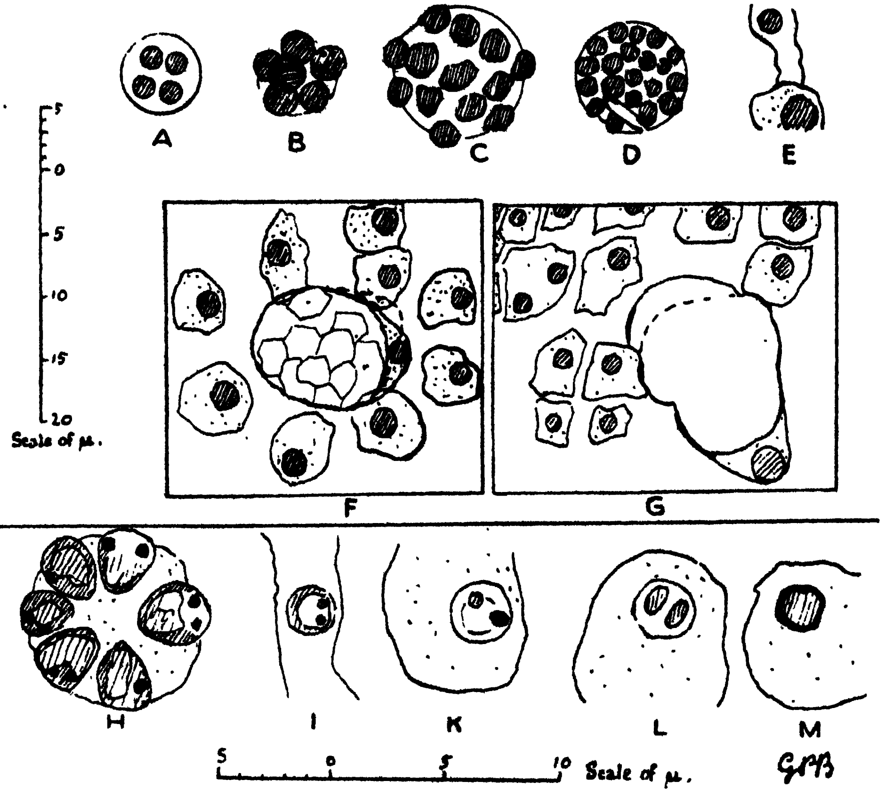
* I will preclude at once the natural conjecture that the red varieties of "*Ascetta primordialis*" (*Guancha coriacea*), described by Minchin, 1892 *c*, p. 16, and myself at Naples, are due to the same cause. The colour in these cases is due to the granules in the porocytes and other ectocytes, of which I have given a description (1892 *b*, p. 482).

† I have measured this on the original drawing, which my regretted friend Professor Vosmaer gave me in 1888. In Bronn's plate the size of the sperm-ball is slightly exaggerated, and a definite circular outline is added, not shown in the pencil drawing, in which the shaded outline is somewhat polygonal.

‡ There is a curious hilus shown near the bottom of this figure; I do not know if this is the "blank space" to which Hartog refers (1906, p. 127) as in *Volvox* marking the original lip of the plate of cells which has bent into a sphere. (Fig. II after Dendy corroborates this view.) It suggests also the "slight thickening in the enveloping membrane" observed by Poléjaeff in the "spermospore" of *Leucosolenia poterium* (1883, p. 33).

Fig. 1.



Explanation of Text-figures.

Figs. A–G are uniformly drawn to a multiplication of 1650 diameters to be comparable with Dendy's plates; figs. H–M are × 3000 diameters. Figs. B and H are after Dendy; figs. I and K after Robertson.

Figs. A–E. *Syncrypta spongiarum*:—(A and B), 4- and 8-celled stages from the flagellate chambers of *G. compressa*; (C), 16 (?)-celled, and (D), 32-celled stages from the flagellate chamber of *Clathrina clathrus*; (E), single monad in the collar-cell of *G. compressa* (the cell is very much contracted and distorted in preservation). (A, E, Plymouth Dec. 14; C, D, Naples Jan. 3; B, H, Plymouth Apr. 24.)

Figs. F–G. Pylocytes:—(F), of *S. raphanus* which had been fed with starch until cessation of the current; (G), of *G. compressa* (the collar-cells are in active division).

Fig. H. The 16-celled stage of *Syncrypta spongiarum* enlarged, for comparison, from Dendy's fig. 89.

Figs. I–M. Ingestion of monads by collar-cells of Clathrinidæ:—(I), "foreign body" (Robertson and Minchin, fig. 48) in a collar of *Guancha coriacea*; (K), "enclosure, ... perhaps of a parasitic nature" (Robertson and Minchin, fig. 85) in collar-cell of the same sponge; (L), "chlorophyll granule?" enclosed in a collar-cell of *Ascaltis cerebrum*; (M), a pyrenoid enclosed in a neighbouring collar-cell of the same sponge.

though "in the centre of the cells there is seen clearly in life a roundish structure, probably a nucleus, or still more probably a pyrenoid." If the material were identical, Dendy, having dealt with it only in the preserved state, would presumably obtain only the conditions figured by Urban, without evidence of the nucleus or pyrenoid described in the fresh cell.

The resemblance of Dendy's figure to Urban's is striking, many of the cells are adhering in pairs, and many (not all) of these pairs are noticeably smaller than their neighbours; one pair (at '2 o'clock' of the drawing, 14 mm. below "ep.") shows the adpressed ellipsoid form of the twins figured by Urban, the diameters of the ellipse being 4 μ and 3 μ. It is worth mentioning also that in the plate the ratio of the diameters of the largest yellow bodies to the smallest is about as 4 : 3: that is, about as $\sqrt[3]{2}:1$, or the ratio of the diameter of a sphere to that of one of two equal spheres formed from it.

The presumption appears strong that the organism drawn by the two authors is one and the same; if so, Dendy's view that the bodies are metamorphosed collar-cells is contradicted by Urban's observation of a normal layer of collar-cells covering the yellow bodies and showing no sign of degradation.

Both authors found their cells resist caustic potash; both found a spherical wall with granular contents (I know of no observation of a resistant cell-wall in collar-cells in any stage of metamorphosis). Dendy's "yellowish colour" may well be Urban's "grüne Farbe" differently treated and viewed by different eyes (Urban states that in other Naples Clathrinidæ he has "orangegelbe, schwefelgelbe, und grüne Farben oft genug gefunden," but I never saw a Clathrinid at Naples I should have described as green).

There is strong resemblance between the descriptions and figures of these cells in Clathrinids by Urban and Dendy, and the descriptions and figures by Schulze (1879 *b*) and Poléjaeff (1884) of "brown spherical algæ from the outer layer of a *Hircinia variabilis*" (1879 *b*, p. 38). The spheres are drawn by Schulze 6 μ in diameter and by Poléjaeff 8 μ and 9 μ, described by Schulze 6 μ to 10 μ. They have a cell-wall and uniform granular contents, and give the sponge a red-brown colour (1879 *b*, p. 25). The only differences are: (*a*) some of the cells attain a diameter 2 μ in excess of any observed by Urban and Dendy; (*b*) Schulze describes the colour as "violettbrauner," whereas Urban found his cells "von eigentümlich rötlicher Färbung."

It appears, therefore, that *Syncrypta spongiarum* is found in all stages from 4 to 16 cells, and as isolated monads, in the flagellate chambers of *Grantia compressa* at Plymouth, where the collared cells ingest it. Its 16- and 32-celled stages appear in the flagellate tubes of Mediterranean Clathrinidæ, where they have been figured as sperm-balls, and there is some evidence that these stages are formed within the mesoglœa of the Clathrinid. On the other hand, a parasitic or symbiotic spherical cell, containing a greenish-yellow and a red pigment, has been found in the mesoglœa of two *Clathrinidæ*, one at Naples and one in the Chagos Archipelago, and is frequent in *Hircinia*. The whole cell is of nucleoid (but not nuclear) character, in a cell-wall which resists caustic potash; it multiplies by binary fission, the daughter-cells separating completely. The cells before division are of the same diameter as the multicellular spheres of *Syncrypta spongiarum*, and contain pyrenoids.

The only indication of transition in the mesoglœa between Urban's dividing but separating spheres and Vosmaer's coherent colony of 16 spherules, is Vosmaer's statement (p. 412) that he can vouch for the truth of Poléjaeff's description (1882) of the "spermaklumpen" arising from the binary division of a spherical cell in the mesoglœa. The context, however, rather suggests that this means merely that Vosmaer had inspected Poléjaeff's preparations; and as these are in the possession of Professor Dendy, I leave the discussion of them to him. It is interesting, in connection with the parasitic cells of *Hircinia*, to note that Poléjaeff remarks in another paper (1883, p. 33) on the strange similarity between the spermospores of Keratosa and those of *Leucosolenia* and *Sycon raphanus*. It is more remarkable in his monograph on Keratosa (1884, p. 72) to find that *Verongia* has "spermospores," like *Sycon*, with a covering cell, but *Carteriospongia* "sperm-balls," like *Oscarella*, in endothelial cavities as described by Schulze. The "spermospores" are 8 μ to 10 μ in diameter, shrunk away (?) from the "covering-cell," which is 14 μ to 16 μ in diameter; but the "spermospore" shows up to 90 black dots—indicating some 150 if it be a hollow sphere. (Note D, p. 319.)

Haeckel's "Samenballen" (1872, Taf. 48. fig. 8) measure 20 and 27 μ across, but no later author describes any object of similar appearance.

Dendy's fig. 87 shows, in my opinion, a pylocyte in which a 16-cell sphere has jammed. It must not be inferred from this that only monads can enter the flagellate chamber. Fig. F shows a pylocyte from *Sycon raphanus* widely open and choked with starch grains. The sponge was killed after 5 minutes' feeding; it will be seen that its diameters are 12 μ × 10 μ. In *Grantia compressa* (fig. G) the pylocytes are almost exactly the same size—from 10 to 13 μ in diameter. There is, therefore, room for the 7 μ spheres to pass, and it seems certain that those in the chambers of this sponge have so passed. Dendy writes (1914, p. 324):—"I have found them, not only in the chambers, but also adhering to the outer surface of the sponge and in the inhalant canals, though, except in the chambers themselves, only in very small numbers. I have also found some evidence of their breaking up into spermatozoa" [*i. e.* monads] "in an inhalant canal."

Syncrypta spongiarum, therefore, reaches and enters *G. compressa* as 16-, 8-, and occasionally 4-celled spheres, the first of which presumably break up into the isolated monads that are also found in the flagellate chambers, where both monads and spheres are ingested by the collar-cells. Neither Dendy nor I have observed any stage suggesting that the 1·6 μ monads grow in the water to the 7 μ diameter of the many-celled spheres. This growth presumably takes place elsewhere and under other conditions; Vosmaer's observation suggests that it is in the mesoglœa of a Clathrinid.* It is therefore a remarkable coincidence that Urban has observed uniformly stained spheres of the same diameter, symbiotic (or parasitic ?) in the mesoglœa of a Clathrinid, where they multiply by binary fission; and that Dendy has figured precisely similar organisms from a Clathrinid on the other side of the world.

There is some evidence that the Clathrinidæ also feed on the monads, and it may be in this way that the new generation of *Syncrypta* enters the body of a fresh host. Fig. H shows the monads of *S. spongiarum* (copied from Dendy's fig. 89, of 16 cells) beside fig. I "a foreign body lodged in the lumen of the collar," copied from Robertson and Minchin's fig. 48 (1910, *Clathrina coriacea*); and fig. K is a collar-cell "showing enclosure, . . . perhaps of a parasitic nature" from their fig. 35 (*cf.* Dendy's fig. 71). Figs. L and M are collar-cells from an *Ascaltis cerebrum* in iodine and sea-water sketched by me at Naples (probably in the month of June), with the note "chlorophyll granule ?" to fig. L; fig. M being one of several collar-cells which showed what was presumably an ingested pyrenoid—"a strongly refractive granule, blue with iodine. It gives the appearance of being blue only on the surface. Professor Paul Mayer says it is not starch."

The monads can enter freely through the pylocytes of the Clathrinids. *Clathrina clathrus*, alive at Naples, showed dermal pores of 8 μ × 4 μ, 7 μ × 5 μ, or 6 μ × 6 μ. This was in aquarium water, which Minchin has shown (1892 *c*) affects this species; but in his plates (1897) the dermal pores of "*Clathrina coriacea*" measure mostly about 4 μ × 3 μ, the largest only being 9 μ × 4 μ (fig. 10); in "*Clathrina* sp." they are 8 μ × 5 μ and 4½ μ × 4½ μ. "*Clathrina contorta*" shows them larger—11 μ × 8 μ and 15 μ × 6 μ.

Of the 19 pores measured any one would allow the passage of a monad, even of 2·2 μ, quite freely. None—and this is important—would allow the entrance of the multicellular spheres observed in the flagellate tubes by Vosmaer and myself; and the spheres were observed by me in *C. clathrus*, of which Minchin (1892 *c*) has shown that the osculum closes before the current stops.

All that can be said as to the possible transformation of ingested monads of 2 μ diameter into the 7 μ red cells of the Clathrinid mesoglœa is that the observations do not contradict it. Dendy (fig. 72) shows in a much altered collar-cell a uniformly stained sphere of 3 μ diameter surrounded by a vacuole; a similar body of 4 μ diameter is enclosed in a phagocyte under the collar-cells in fig. 67. He describes in the collar-cells (p. 361) "circular inclusions of large size, around which vacuoles frequently make their appearance"; they stain like the reserve granules. Robertson and Minchin have four other interesting figures of collar-cells with spherical enclosures, of which fig. 32 shows an almost uniformly staining sphere of $4\,\mu$ diameter surrounded by a large vacuole. Dendy's fig. 66 and fig. 84 show three nearly spherical cells of $7\,\mu$ diameter in phagocytes; two have a bilateral symmetry or are commencing division.

If Dendy's theory of spermatogenesis may be taken as withdrawn, these appearances are all unexplained. It is therefore open to us to conjecture that the monad of *Syncrypta spongiarum*, after ingestion by the collar-cell, is not digested, but becomes surrounded by a vacuole in which it grows to a diameter of $4\,\mu$, inducing, in *Grantia compressa*, considerable abnormality in the containing collar-cell. At this size it appears to pass into the mesoglœa, where it increases to the $7\,\mu$ diameter of Urban's symbiotic algæ and Dendy's yellow bodies; but *G. compressa* appears to have specialised a system of phagocytosis which prevents its multiplication, so that it may be only in the Clathrinids and *Hircinia* that the parasitic (or symbiotic) generation attains success *.

On this hypothetical history we should assume that conjugation occurs between the monads before ingestion by the collar-cells, that the zygote in a hospitable sponge gives rise to many generations of parasitic red cells, but that their symbiosis, if it be true in Clathrinids, is rejected by *Grantia*. With the onset of unfavourable conditions the red cells, instead of further multiplication of their like, form spheres of coherent gametes which escape to seek a new host and reinforced vitality †.

The fact that among calcareous sponges the red cells have hitherto only been recorded in occupation of two individuals militates strongly against Urban's conclusion that they are here symbiotic. Dendy found no collar-cells in "*Leucosolenia gardineri*" which was possessed by them. The suggestion is rather that this organism is a dangerous parasite of all sponges but *Hircinia*, whose physiology is accommodated to it, perhaps in true symbiosis. It appears to be destroyed in *G. compressa* by phagocytosis, and the necessity of repelling this enemy must be taken into account in considering unexplained phenomena in the histology and anatomy of sponges.

If the suggested hypothesis be correct, and the red, violet-brown, and

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* Dendy describes in the "ova" of *Leucosolenia gardineri* (p. 4) "conspicuous spherical bodies .... closely resembling in appearance the yellow bodies .... but more variable in size." Their being described inside the *nucleus* would prevent us guessing that this could be phagocytosis; but the nucleus "has an irregular outline and no nuclear membrane."

† The pyrenoids observed by me in *A. cerebrum* suggest that the containing monads have been digested; Robertson's fig. 34 and Dendy's fig. 70 seem indicative in the same direction. It is possible that the newly-formed zygote can resist digestion by the collar-cell, but that unpaired gametes merely supply food for the sponge.

(in preservation) yellow spherical "algæ" found in sponge-mesoglœa are the alternate generation of *Syncrypta spongiarum*, it seems possible that the unusually small size of this species among its allies may have been developed with the advantage of enabling the monads to enter the prosopyles of sponge-chambers, and so be ingested and pass into the tissues of its host. From Poléjaeff's plate 5, the prosopyles of his *Cacospongia* and *Carteriospongia* are mostly about 3 μ in diameter; a monad of 2·2 diameter is therefore very closely the largest size which can be sure of entering the apertures of the screens which protect its prey.

It is noticeable that in fresh water, Pascher (1910, p. 37) finds *Syncrypta volvox* only frequent in spring (April) and September, more rare in the summer. This allows the inference that the months of greatest sunshine are passed in a more important Palmella stage.

Notes on the Physiology of Sponges.

By G. P. BIDDER, Sc.D., F.L.S.

(With Text-figures.)

[Read 6th May, 1920.]

THE two preceding papers allude to some questions in histology and physiology, the further discussion of which seems better placed under a title where they may be expected.

NOTE A.—*Cercids* (p. 301).

Minchin's "minute wandering cells" (1897, p. 499) are clearly elements of great interest and importance. As such it is convenient that they should have a short and pronounceable name, and I propose the name "cercids" from the Greek *κερκίς* (*κερκίδος*), which in two of its meanings well describes their form; the shape when the nucleus is in the middle sufficiently recalling that of a "shuttle[*]," while the wedge-like shape manifested when the nucleus is terminal may stand for the "cuneus" of seats in a theatre or amphitheatre (Pl. **24.** fig. 7).

Minchin's description of their origin and history in *Clathrina coriacea* takes a different aspect when, in 1908 (p. 354, fig. 71), he draws them also in *Leucosolenia*; and again with my observation of them, recorded above, as bursting in a swarm from the wall of *C.* (*G.*) *coriacea*. In Dendy's careful drawings (1914, pl. 24 and pl. 26) there are somewhat similarly shaped objects shown in *Grantia compressa*: fig. 44 inside an ovum, fig. 80 in a problematical spherical enclosure.

But my cercids in *G. coriacea* measured 4 μ to 5 μ long by 0·5 μ wide, except at the nucleus, which is 1 μ to 1·2 μ in diameter. Minchin's "minute wandering cells," in the same species, are in his figs. 17, 19 about 7 μ long with nucleus 1·4 μ. *Minchin's "minute amœbocytes"* in *Leucosolenia* measure 3 to 5 μ × 1 to 1·5 μ (a nucleus is not shown); while the objects drawn by Dendy are only 2 μ × 0·3 μ with "nucleus" 0·6 μ. I define the name "cercid" as applying to the mobile and emigrant cells of *G. coriacea*, leaving it to the future to determine if truly homologous cells occur in *Leucosolenia* and *Grantia*.

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[*] The first meaning given to *κερκίς* by Liddell and Scott, following Smith's Ant., is "the rod or comb by which the threads of the woof were driven home"; but in this they are wrong, and "shuttle" is the true meaning, on the authority of Butcher and Lang (Translation of Odyssey, V. 62); Lang, Leaf, and Myers (Translation of Iliad, XXII. 448); Edwards (A Companion to Greek Studies, Cambridge, 1916, p. 520), Blümner (Gewerbe und Künste, 1875, i. 134); and my friend Professor Henry Jackson, who told me of the error. L. and S. give no Greek word for "shuttle," rightly omitting *πανοῦλκος* given by Smith.

The suggestion is strong that cercids, produced by the repeated division of archæocytes, are in *G. coriacea* locomotor fertilizing elements which leave the body and drift in the water, to enter eventually the oöcyte of another sponge. Whether they first develop a flagellum, and whether they co-exist with or are replaced by the flagellate spermatozoa described (to the Linnean Society on Dec. 11th, 1919) by Dr. Gatenby in *Grantia*, or the gregarine-like objects which I have figured (Pl. **24.** figs. 4, 5, 6) emerging from [or entering—see Postscript, p. 302] the cloacal wall of *Sycon*, it would as yet be futile to discuss.

[*Sept.* 20, 1920.—On the day that this MS. goes to press, I have a letter from Mr. Julian Huxley, containing sketches of small cells which he has discovered in the tissues of sponges. They have closely the appearance of Plate **24.** fig. 7, and judgment on the function of cercids must be suspended until his observations are available.]

NOTE B.—*Cessation of the Current* (p. 301).

When the collar-cells are completely covered by a lining of invading porocytes (see 1892 *b*, fig. 2; 1897, p. 487; 1900, fig. 42, F; and 1908, p. 326), there can be no current; and a motile spermatozoon could enter by the osculum in those species (as *Ascaltis cerebrum* and *A. reticulum*) in which the latter cannot close. Assuming that it is to the granules of the porocytes that the Clathrinidæ owe their characteristic scent, the spermatozoa, after the osculum is passed, will enter a highly odoriferous chamber, to the porocyte-lined walls of which they will be strongly attracted.

The current may also be completely stopped by the clogging of the pylocytes and, in Heterocœl sponges, by the choking of the afferent canals. I have found this happen in ten minutes to *Leucandra aspera* fed with indigo, and in half-an-hour, when fed with Indian ink, the current was very much diminished; sea-water, milk-white with starch, stopped the current in two minutes. In nature similar cessation must be at times caused by unusual turbidity of the water.*

Outside these two cases, it may be assumed on purely general grounds that pathological conditions may kill or paralyse the collar-cells, while leaving the ova still susceptible of successful fertilisation. Thus, Annandale (1907,

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* That such cessation is not due in Calcaronea to reflex closure of the pores, as stated by Lendenfeld (*cf.* 1895, p. 33), is proved by the fact that sections show the pylocytes widely open and choked with starch grains (see *ante*, p. 308, fig. F). Parker's experiments (1910 *b*) on *Stylotella* have led him to the same conclusion, and to a similar disbelief in Lendenfeld's assertions.

The form of a pylocyte, viewed from one of the surfaces, is strongly suggestive of a sphincter, but I believe this suggestion to be delusive. A pylocyte is a perforated cell whose differentiation is to make intracellular communication between one cavity and another; it is comparable to a cell in the channel of a nephridium, and not to a muscle-cell; it is a radial cell perforated radially, not a tangential fusiform cell whose ends are united, and the forces exerted by the cell oppose those of surface-tension which would obliterate the lumen,

p. 387) observed in India that *Spongilla* ceases its currents during the hot hours of the day, the oscula and pores remaining open ; he deduces that the flagellar motion must have ceased. My experiments on the currents of Calcaronea at Naples do not show this, but the records show some evidence of a possible reduction in power in the hottest hours. But, for the question before us, a rise in temperature sufficient to paralyse the flagella of the collar-cells might be expected also to suspend the movements of the spermatozoa, so that entrance by the osculum would not then be effected.

I cannot find any satisfactory record of an observation showing with certainty that in a sponge, with its apertures open and its collar-cells unchanged, motion of the flagella spontaneously stops and begins again.

Such is certainly the impression gained on first experiments with living sponges; but as experience makes allowance for injury, temperature, suffocation, obstruction by air-bubbles, etc., the impression steadily diminishes. The result of rather prolonged work on the living collar-cells (1895) was to make me regard a motionless flagellum as a sign of death, or danger of death, in the cell which bore it.

NOTE C.—*On Odour and Excretory Granules* (p. 299).

In regard to the stronger and more pleasant odour possessed by Clathrinidæ as compared with *Sycon*, *Grantia*, etc., I am pleased to be corroborated by my friend, Mr. L. R. Crawshay, who very kindly made observations on the shore at Plymouth, collecting *Clathrina coriacea* and *Sycon* separately in stoppered bottles. His experience accorded with my statement, though, the season being mid-winter, the conditions were not very favourable.

There is evidence of a direct character that considerable difference exists between these two groups in the nature of the granules formed by the porocytes and ectocytes. I found indigo-carmine deposited freely in the ectocytal and porocytal granules of *Clathrina clathrus* (1892 *b*), *Guancha coriacea*, and *Ascaltis cerebrum* and *reticulum* ; but never was able to demonstrate deposit with *Sycon raphanus*, *Leucandra aspera*, or *Grantia compressa* : and Cotte (1903, p. 459) also obtained negative results with *Sycon raphanus*. The facts suggest a modification of my views as to excretion (1892 *b*, compare Urban 1903 and Minchin 1908)*. That is to say, it appears logically possible that these refractive lipoid granules, of which I have recorded (*l. c.*) many puzzling reactions, are not in all sponges formed by a process which also secretes sulphindigotate of soda; but that in the Calcinea (and possibly at sexual times in *Sycon*) an odoriferous body is added which is so formed.

Cotte has a very interesting observation (*l. c.* p. 528), that the individuals of *Sycon raphanus*, which were "exceptionellement riches en pigment jaune

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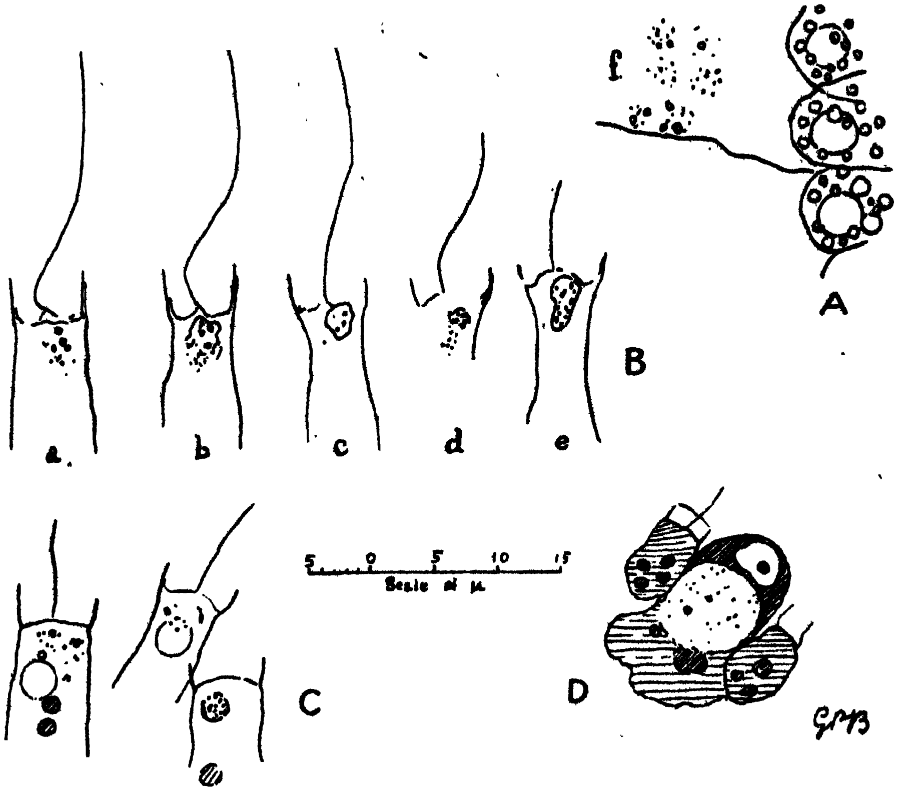
* See also footnote, p. 323.

FIG. 1.



Explanation of Text-figures.

All figures are approximately × 1650 (the scale of Dendy's 1914 plates).

Figs. 1 A, B, C are from *Grantia compressa*, fig. 1 D *S. raphanus*.

Fig. 1 A. Collar-cells from a sponge gathered at low tide, 27 hours out of the water and replaced in sea-water for 10 hours, flagella moving rapidly. At *f* a small portion is drawn of one of the aggregates of excreta which were in the chambers. (Feb. 7.)

Note that after their long purging and deprivation of food the collar-cells show perfectly transparent spherules or vacuoles and protoplasm in place of the greenish spherules and granular protoplasm of normal health. Note also that the nuclei are not pear-shaped as described by Minchin, but spherical as I have always found them in life, except that occasionally they are ellipsoidal owing to constriction by the cell-wall in suffocation (see 1895, p. 23, rediscovered by Cotte, 1902; see 1903, p. 453). Progressive suffocation is shown in Fig. 1, B.

Fig. 1 B. *a*, *b*, *c*, *d*, *e*. Five successive sketches drawn from the same cell, showing a moving globule of fæces in a position which must be just under the iris-membrane. From a sponge 2½ hours exposed by the low tide, 2 hours in sea-water after gathering. Flagella very active. (Jan. 8.)

Fig. 1 C. Living collar-cells, showing fæces in a similar position. From a normal sponge. Basal spherules (shaded) are greenish. In the right-hand cell the spherical dotted globule was brown*. (Jan. 20.)

Fig. 1 D. Amœbocyte with vesicular nuclei and enclosing a ball of fæces, projecting between two collar-cells into the chamber. From *S. raphanus*, fed with carmine 20 minutes, 18 hours' rest, killed osmic acid, decalcified formic acid, not otherwise stained.

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* Comparison with observations made at Plymouth since this paper was written shows that the brown globule was clearly a *Syncrypta*.

d'or, étaient en état d'élaboration sexuelle très active (mois de Janvier)." In the *Sycon raphanus* of the aquarium, with which I mostly worked, I never remember seeing any golden-yellow pigment, so that I am unable to do more than transcribe the passage.

NOTE D.—*The Fæces of Sponges, and Phagocytosis* (pp. 306, 310).

The fact that Dendy occasionally found in inhalant canals the "small masses of granules" which he describes and figures (1914, p. 365, fig. 93) does not discredit my interpretation of them (1895, p. 18, fig. 13 *a*) as being fæces. It is obvious that, even in the sea, the fæces of another sponge may often drift into the afferent system; but the sponge from which Dendy drew his fig. 93 was examined two or three hours after it was collected, and was watched in a glass dish where "there was an active current issuing from the vent, bringing with it a quantity of fine yellowish-grey sediment, which collected at the bottom of the glass dish" (1914, p. 320). In that small volume of water any particles carried out in the oscular stream, which were too small or light to sink rapidly, would be borne again back into the sponge through the inhalant canals.

That they are not spermatozoa is proved by my finding them in the three winter months, to which that part of my work on the living *Grantia compressa* was limited. I found (1895, p. 11) that this sponge is annual at Plymouth, larvæ being recorded in May and July, and only the young sponges produced by them being found in September, when there are none but minute individuals. Dendy rediscovered this, and considers that the breeding-season "would seem to begin in the first half of April," when "comparatively few embryos are found" (1914, p. 321), his visit to Plymouth being April 10th to April 22nd. My friend Professor Dendy will therefore agree with me that a drawing (1895, fig. 13 *a*) made on Feb. 7th was not from a huge swarm of spermatozoa, and my first observation of these fæcal agglomerations was in December. [For breeding-time see also Orton (1920) pp. 340, 341.]

These extremely large masses were met with in sponges which had been subjected to experiment in regard to their endurance of low-tide conditions, and it is worth remark that the sponge from which Dendy's fig. 93 was drawn had been gathered about mid-day April 18th, 1912 (1914, p. 320), and therefore at dead low-tide, the day before an exceptionally deep spring-tide. It is obvious that in sponges which have been out of the water for many hours the cellular excreta from the collar-cells, if there be such excreta, must accumulate for all those hours in the flagellate chambers, instead of being steadily thrown out in the normal way through the oscular stream as described by Bowerbank (1858, p. 121)* and others. There is, therefore, *prima facie* reason for supposing that any finely granular substance found to accumulate in the chambers under these conditions is composed of such cellular excreta. And, as Vosmaer and Pekelharing point out (1898 *b*, p. 10), the "clods of detritus" are many times larger than the prosopyles, and consequently could not have entered through the prosopyles, but must necessarily have been formed within the chambers.

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* Compare also 1857, last paragraph but one (p. 15 of the reprint):—"If the sponge" some time after feeding with indigo "be now removed into fresh water, the ejection of molecules of indigo continues for hours to be slowly effected."

Add that, in such sponges, I found in life that "almost every cell possessed a globule containing angular dark particles," sometimes, as in (1895) fig. 4, "projecting on the surface between collar and flagellum. These globules were observed and drawn moving in the distal protoplasm of the cells;" (Note G) "there were numerous bodies of similar appearance (*cf.* fig. 13 *a*) floating freely in the chamber" (1895, p. 18). The figures illustrating this statement lost detail in their reproduction; those appended here are on the full scale of the sketches (fig. B enlarged to the scale of figs. A and C). They are corroborated by Cotte's observation (1903, p. 559), in a *Sycon raphanus* which had absorbed tournesol, of two blue spherules (each containing a darker blue point) being ejected by choanocytes; the spherules being thrown out from the annular space between flagellum and collar.

In regard to the gelatinous matrix of the fæces, "I have often suspected, from paraffin sections, that the food vacuoles of sponges are filled with some gelatinous matter, coagulated in preservation" (1895, p. 18). Cotte (*l. c.*), in *Reniera simulans* fed with carmine or lamp-black and returned to clean water, observed afterwards "des bols fécaux" in the flagellate chambers. "La substance hyaline qui agglutine les corpuscules solides indique vraisemblablement qu'il y a eu ingestion préalable par les choanocytes, et que les choanocytes les ont ensuite abandonnés." Greenwood and Saunders (1894, p. 449) describe a type of digestion in Myxomycetes where "any nodule of food as yet unchanged is invested by a homogeneous mucilaginous sphere, or in later stages . . . . a viscid mould or cast of the interior of the vacuole is formed" . . . . "We think that some element present is not only undissolved but insoluble, and comparable probably to that mucilaginous residue which gives so distinctive an appearance to the egesta of many Infusoria." Discussion with Miss Greenwood greatly influenced my conclusions.

It is interesting that Dendy's description, quoted above, verifies the old observation of Carter (1849, p. 98) that the "fæcal matter" issuing in the oscular current is markedly heavier than water. It has been suggested to me by a friend that this may indicate the deposit of calcium salts in the fæcal boli, and that to these may be in part due the refractive or opaque granules which characterise the boli. In any case, I venture here to repeat from another standpoint the comparison which Dendy made between these cellular fæces in the flagellate chambers and the "masses of granules" figured as spermatozoon-heads by Poléjaeff and other authors. If the sign of completed digestion in the collar-cell be the complete replacement of the food-vacuole's contents by a pellet of gelatinous matter containing refractive or opaque granules, this is likely to be also the process of digestion in a mesoglœal phagocyte *. The evidence is that the "masses of granules" are the last products of digestion, and within a phagocyte, or group of phagocytes, may be taken as showing where the combat with an intruding organism has been victorious and complete.

This speculation has partly originated in the attempt to explain the cell drawn in fig. D, alluded to at the meeting of the Linnean Society on Dec. 11th. With a superficial resemblance to a pylocyte, it differs in its thick body and large vesicular nucleus; in each of these particulars it resembles Dendy's fig. 81. Also the plane of its crescent is radial instead of tangential to the chamber into which it projects, instead of framing an aperture in the wall.

The appearance of the cell, either in fig. 1 D or in Dendy's fig. 81, is unquestionably that of a gonocyte. In describing my feeding experiments, and confirming my previous observations that the gonocytes feed on the basal spherules of the collar-cells, which are stores of digested food (1892 *b*, p. 474; quoted 1893, p. 220; rediscovered 1914, pp. 328, 344), I wrote :—" A large number of gonocytes are in contact with collar-cells which contain plentiful carmine; in only two of them I found carmine-grains, and it is tempting to deduce that vacuoles and undigested food do not pass into the gonocyte" (1895, p. 30). Cotte (1903, p. 448) uses similar language :—" Les coupes de *Sycandra* montrent quelques grains de carmin ou de charbon englobés par des amibocytes; c'est là, on peut le dire, une véritable exception." But our experiments show only that the amœbocytes of Calcaronea do not ingest particles which reach the choanocytes from the water of the chamber. This negatives in no way their power to engulf foreign bodies which they may find in the mesoglœa. And beside the classical experiments of Metschnikoff (1879), Cotte has shown that they have this power in *Reniera* (p. 448) and *Spongelia* (p. 455); while Dendy (1914) has given a most interesting description of phagocytosis by oöcytes and other amœbocytes in *Grantia compressa*.

I interpet fig. 1 D as an amœbocyte which has digested some foreign substance encountered in the mesoglœa, and is dragging the excreta to be cast out into the efferent water of the flagellate chamber †. And Dendy's fig. 81 indicates that the substance partially digested there, wholly digested in my fig. 1 D, is a lightly-staining sphere of 6 μ diameter (with nine spots, staining more darkly, in fig. 81). The indications seem to me that these figures, Dendy's fig. 85, and many others in his very interesting plates—all record stages in the war against *Syncrypta*, which appears to be carried on successfully in *Grantia* either by the gonocytes themselves, or by other amœbocytes which have this function [*].

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* [Since this paper was read I have seen van Trigt's interesting work (1919, p. 162), in which he records similar fæces formed by the amœboid cells of *Spongilla* and by the walls of the efferent canals.

Van Trigt considers that this sponge feeds upon and digests the cells of the green alga which give its colour.]

† [*Cf.* van Trigt, *l. c.*]

Most interesting in this connection is Poléjaeff's statement (1884, p. 72) as to "spermospores" in *Verongia* :—"When ripe they recall so vividly the corresponding formations in *Sycon raphanus* (with the sole distinction that while in this latter instance the nucleus of the covering cell in quite ripe spermospores is in most cases indistinct, in *Verongia* I find quite empty capsules, nevertheless, provided with it)."

All the "covering cells" represented in *Verongia* (pl. 10) contain only masses of granules; and similar masses are in *Carteriospongia* in an endothelial chamber, as described by Schulze (and verified by Poléjaeff) for *Oscarella*, *Aplysilla*, etc. I suggest that the nucleus of the "covering cell" is indistinct where the contained *Syncrypta* has killed the amœbocyte which ingested it, and that those in *Verongia* are the nuclei of amœbocytes which —as shown by their granular contents (as in my fig. 4)—have destroyed the *Syncrypta*, themselves uninjured. An endothelial capsule occurs in *Carteriospongia*, instead of a covering cell as in *Verongia*, because the heap of granules is 40 $\mu \times 15\,\mu$ instead of 9 μ in diameter, showing that the digested substance was too large for one phagocyte to contain. Such conclusions merely assume a process wholly comparable with the destruction of *Oscillatoria* by the amœbocytes of *Spongelia* which is described by Cotte (*l. c.* p. 455).

As Vosmaer said (1887, p. 412) :—'The structures which many spongologists have set forth more or less positively as spermatozoids may have been so or may not; in many cases it remains doubtful.'

Note E.—*Origin of Sponges.*

If the hypothesis be adopted that the granules of porocytes attract spermatozoa, a possible history of the origin of sponges is suggested.

If we construct our imaginary ancestral sponge on the lines of the *Sycon* amphiblastula, illumined by *Protospongia*, we find a colony of flagellate collared cells whose function is to obtain nourishment, surrounded by their associate archæocytes, which receive the digested nourishment and alike excrete in a manner possibly protective for the colony * and are charged with its reproduction.

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[*] I am unaware how far, by those who have worked at these problems, phagocytosis and conjugation are considered cognate or opposite. My friend Miss E. R. Saunders tells me that in the revival of a plasmodium of Myxomycetes from the sclerotial condition, as each sclerotial cyst is enveloped by the advancing plasmodium, it is uncertain for a moment whether a vacuole will be formed round its protoplasm and this be digested, or whether it will revive rapidly enough to burst to the moisture, and unite alive with the syncytium. This alternative absorption as food, or as a living partner, suggests that conjugation may arise from attempted phagocytosis.

At this stage we may conceive the secretion of an attractive odour to have become permanently associated with their nitrogenous excretion, with the advantage of more frequent reinvigoration of the stock by conjugation with locomotor units from other colonies.

Development led to differentiation of purely reproductive cells from those charged with excretion, the reproductive cells being placed in greater safety by a covering of the excretory cells. The latter would still attract the locomotor units, which, when engulfed, they would pass on for nuclear union with the gonocytes. This absorption from the exterior and transmission to the interior would be simplified (as the reverse process has probably been in nephridial tubes) to perforation (*cf.* 1892, p. 182). Misdirected perforation, placing the excretory surface of the sponge in communication with the flagellar surface instead of with an oöcyte, would sporadically occur, and when so occurring would lead to a sudden increase in the hydraulic efficiency of the flagella as a food-catching apparatus, supplies being thus brought to centrally placed choanocytes which otherwise could only be reached by water which had passed over their neighbours. Such misdirected perforation would therefore be perpetuated by the increased prosperity of those colonies in which it happened, their form being now in essence that of the rudimentary Olynthus; from this upwards "all transition from more to less primitive canal systems exhibits an increase in the ratio" that determines the mechanical efficiency of the canal system (1888; 1895, p. 29).

The cercids are fragmented archæocytes (see Minchin 1897, p. 500) which (*ante*, p. 300) break out into the surrounding water and effect conjugation with the archæocytes of other colonies.

My excuse for printing such a fanciful story is the extreme difficulty of forming any conjecture as to possible value to the organism of the intermediate stages in the evolution of a hydraulic system supplied by intracellular pores (*cf.* MacBride, 1918, p. 52). If the pores were multicellular, we might conceive them as originating as grooves or furrows in the flagellate surface, with the advantage in every stage of bringing better supply to the more central flagella. Such an evolution would fit in with many embryological observations, and there is so much evidence that sponges are polyphyletic that it is not impossible that both developments have occurred†. But in both Calcinea and Calcaronea we know that the pores are intracellular.

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* The nitrogenous excretion of the archæocytes may be beneficial to the colony by being either repulsive to foes or attractive to friends. But, in view of the known defæcation by collared cells, these probably get rid of their own nitrogenous poisons, and I do not now believe that in this sense either the primitive archæocytes or the specialised porocytes excrete for the whole colony. Loisel's criticism on this point (1898, p. 203) is quite just.

† In the Donatiidæ and the Hexactinellida there is no evidence of the presence of pore-cells, and it is doubtful if in either of these groups there is any sexual reproduction.

Minchin (1900, p. 49) suggests that the pore-cells may primarily be nutritively phagocytic in function, and therefore have come to surround pre-existing afferent pores. The hypothesis does not seem *a priori* persuasive; and it does not fit well with the facts, since we have no evidence of pre-existing pores, nor, in these sponges, of any prosopyles which do not perforate porocytes *.

[POSTSCRIPT.

NOTE F.—*Oögenesis in* Sycon.

Dendy's derivation of the oöcytes from collar-cells (1914) in *Grantia compressa* is not in harmony with my own views; but on re-examination of my preparations I cannot claim that they disprove it.

His figs. 2, 3, 12, 13, 14 (as also 62, 66, and 68) are from a sponge which had been a week in the aquarium circulation. It appears possible, therefore, that he observed the early stage of the pathological changes in the flagellate chambers, of which I have recorded the condition after a month in the aquarium (1895, p. 27). It is remarkable, however, that in my pathological specimen, though the highly gelatinous mesoglœa contains many cells of the size and appearance of collar-cells, there are scarcely any recognisable gonocytes or cells which resemble gonocytes in size or character.

I agree with Dendy that the ova are found free in the cavity of the chambers, strange as this appears, and that such is the interpretation of the "larger nucleate cells, possibly Protozoa, partly enveloped by the distended collars, sometimes more than one cell converging on them," which I described in 1895 (p. 31), and which are well indicated in his figs. 11 and 74 (in the latter case the ovum is called a "primary spermatogonium"). I found in sections of *S. raphanus* unmistakable ova in the lumen of the flagellate chamber and one just passing through the wall, and I sketched at Plymouth (April 1920) such an ovum alive in the cavity of a flagellate chamber of *G. compressa*, seated with pseudopodia stretching over the free ends of half-a-dozen collar-cells, in outline ludicrously like an octopus. Between the vesicular nucleus and the free ovoid surface was a comet-shaped streak or arc of minute green fragments, suggesting that it had used its freedom to feed on and digest an alga, thus supporting Dendy's suggestion on pp. 323, 335 (1914).

NOTE G.—*Migration of the Nucleus in Collar-cells.*

In fig. 1 C the nucleus is visible in two cells, and is seen to have moved downwards to allow of the escape of the fæces through the aperture in the iris. Such displacement must also occur when any large mass of food is ingested, and *Syncrypta* spheres commonly do not pass the nucleus (*cf.* fig. C). Hence, Hammer (1908) found the nucleus often not distal, and his fig. 85 shows such a nucleus, with the agglomeration of ingested foreign bodies which have forced it down. He correctly quotes me as having watched the living nucleus moving in the protoplasm, but I found its common situation apical. The fact that his observation of a usually basal position in life was contradicted by his stained sections indicates that in the living cell a food-vacuole was mistaken for the nucleus—in like manner as I described the nucleus at first as a vacuole (1895, p. 18).]

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* Cotte (1903, p. 434) considers that there is a general power of cell-perforation in the pinacocytes of *Reniera*, and quotes Topsent for similar perforations of the contractile cells of this species and of *Cliona*.

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* These are the dates on the title-pages. I have been given the honour of superintending the publication of Vosmaer's Bibliography of Sponge Literature, and in this these works are entered under the years in which they were actually issued—the 'Challenger' Calcarea in 1884 (note date of its preface) and Bronn in 1886.

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On certain Nuclear Phenomena in the Oocytes of the Gall-fly *Neuroterus*.

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(With two Text-figures.)

[Read 6th November, 1919.]

DESPITE the existence of a very considerable literature dealing with insect cytology, there is still the most meagre knowledge of the history of the nucleus in the oocyte, particularly in the case of the Hymenoptera, though this group has attracted many investigations of a cytological nature on account of the frequent occurrence of parthenogenesis among its members. Recent work by Doncaster on the process of maturation, and by Hegner, Martin, Silvestri, and Gatenby on the earlier stages of oogenesis in certain of the Hymenoptera parasitica, have revealed somewhat unique phenomena which call for further elucidation. The present communication contains some observations of a preliminary nature which shed light upon the character of the mitotic figures which occur during the formation of polar bodies in this group.

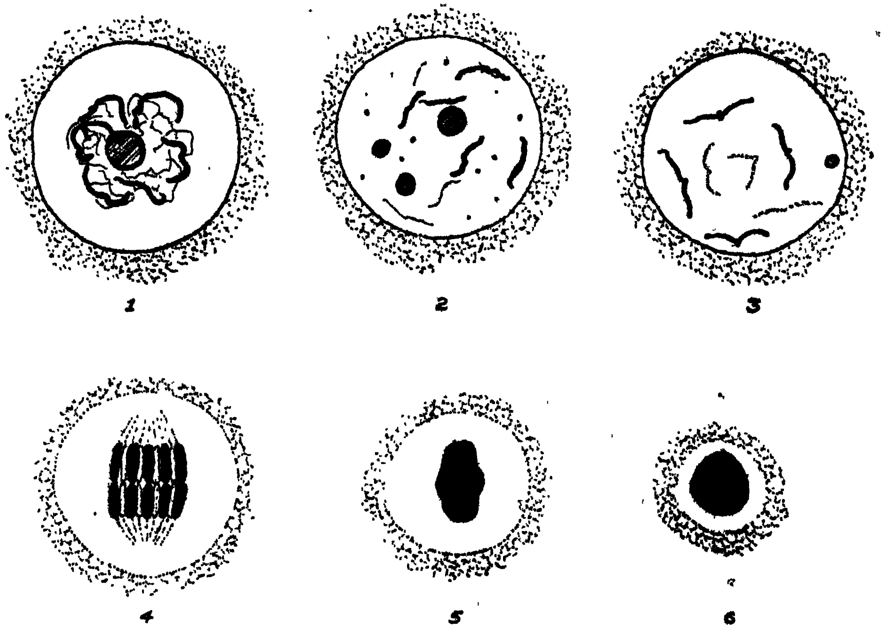
Gametogenesis in the Gall-fly *Neuroterus* has already been made the subject of three memoirs by Prof. Doncaster, to whom I am indebted for the material of the present note. In describing the maturation of the ova, attention was directed to the fact that an unique type of ookinesis occurs, in which, to quote Doncaster, " the first division takes place by the drawing out of threads (probably double) on each side of the nucleus ; the reticulum becomes absorbed in these threads, which form two groups of parallel chromosomes on a spindle. These chromosomes then divide, probably longitudinally, giving rise to the group which forms the egg and three polar groups of chromosomes." An apparently similar type of maturation division was described nearly twenty years ago by Henking in the Cynipid genus *Rhodites*. Quite recently Hegner and others mentioned above have made cursory references to the existence of a precocious maturation spindle of a normal type in certain species of Chalcids, Braconids, and Cynipids ; and, according to these authors, instead of proceeding to pass into anaphase, the chromosomes, in the form of end-to-end pairs, condense into a compact nucleus like that found in the full-grown egg of *Rhodites* and *Neuroterus*. It was therefore thought desirable to attempt to correlate these phenomena if possible.

Oocytes of the agamic generation were chosen for study, the larvæ of the spring brood being entirely females. A few pupæ of *Neuroterus lenticularis* were collected by Prof. Doncaster, but as it was difficult at the time to procure many, the closely-allied species *N. numismatis* was also studied, late pupæ and egg-masses of newly-hatched flies being preserved in addition to the November material. For the latter Flemming was used, egg-masses being preserved in Bouin or Gilson's fluid. Sections were cut 4–6 m. in thickness and stained with Heidenhain's iron hæmatoxylin and eosin. The preparations were examined with a Zeiss ·2 immersion and apochrom. ocular No. 12.

The Somatic Mitoses.

Fifty counts were made of the dividing nuclei of the developing wing, nervous system, and follicular epithelium of *Neuroterus numismatis*. The average was 19·2, 26 giving 20 and the rest 18 or 19. Some of the figures giving 20 were very clear, and there is no doubt that the diploid number for this species is the same as for *N. lenticularis*, viz. 20.

FIG. 1.



1–6. Pairing of the chromosomes and formation of the abortive maturation spindle in *Neuroterus numismatis*.

Very clear figures of abnormal mitoses were found in the hypoderm cells of larvæ of *N. lenticularis*. Doncaster has figured in his second paper the anaphase of one of the giant cells which lie below the epidermis showing at least 50 chromosomes at each pole. In several cases of cells of the hypoderm itself I noted the occurrence of 30 chromosomes at each pole. In one case this number (30) was quite unmistakable. In three nuclear divisions in the same region the haploid number occurred; and it is perhaps of some significance that the two numbers are complementary. It is thus possible that the occurrence of the haploid figure may be due to a difference of polarity—pathological maybe—in the dividing nuclei.

The Development of the Oocyte.

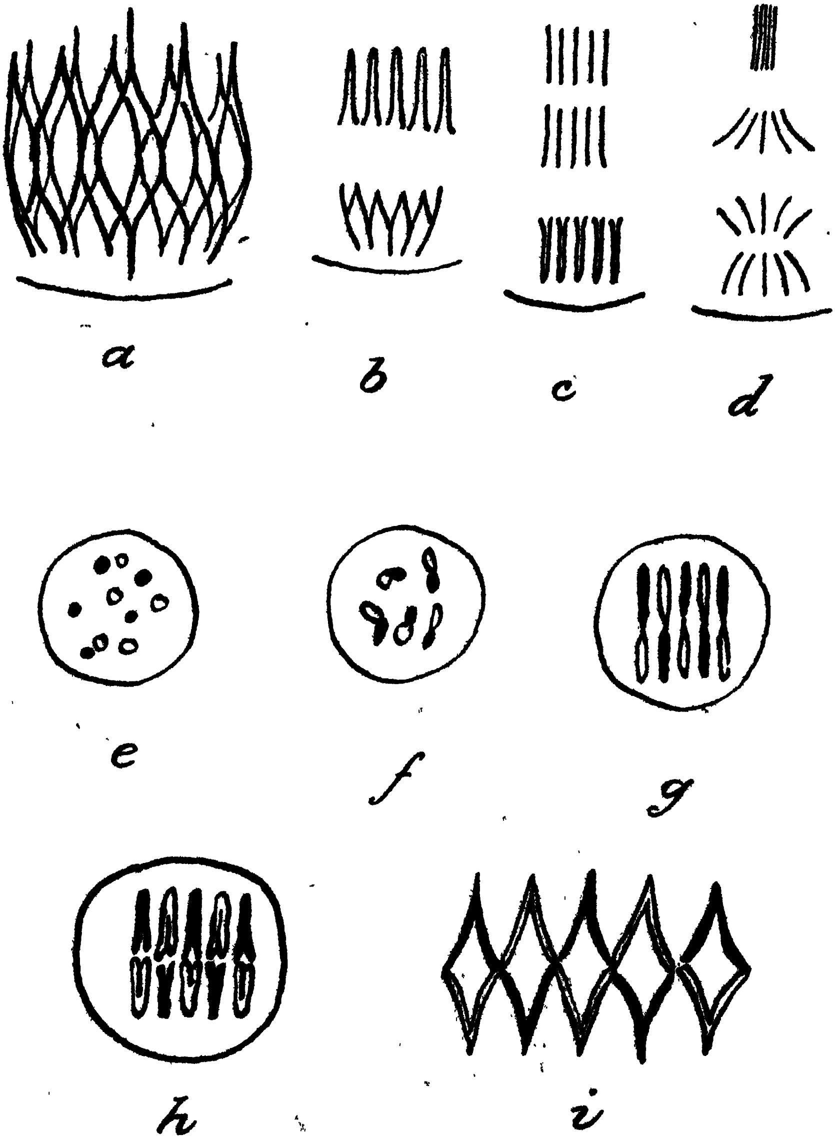
As there are two kinds of ova produced by the agamic generation in *N. lenticularis* (viz. those which undergo maturation and give rise to males, and others which do not form polar bodies and are female producing), it appeared possible that differences might occur in different individuals during the synapsis stages. No points of contrast between the very young oocytes of different agamic females could be detected either in *Neuroterus lenticularis* or in *N. numismatis*, although the ovarioles of more than twenty individuals were examined.

Synapsis occurs in the upper part of egg-tubes of ovaries in which the former have just become differentiated. The cells of this region are arranged in groups of about 8 to 16, and synizesis nuclei can be seen before it is possible to distinguish nurse-cells from oocytes. Subsequently the chromatin material of certain cells, which are to become nurse-cells, undergoes fragmentation into very numerous granules. Their nuclei later exhibit one or two large karyosomes of irregular shape: these at a late stage disintegrate and are ejected into the cytoplasm. During the growth period it is not possible to detect definite chromosomes in the oocyte nucleus, the chromatin content of which greatly loses its staining capacity. One or two karyosomes and a plasmosome are found often lying on the outer side of the nucleus. As in *Andricus*, there is no oosoma at the posterior end of the egg like that described by Hegner in *Diastrophus* or the body referred to by Weissmann in *Rhodites*. There are no secondary nuclei.

The Maturation Spindle.

Later phases were studied exclusively in *N. numismatis*. The oocytes of the March pupæ no longer display the diminished staining capacity described above. The diploid number of chromosomes is seen to be dispersed throughout the nucleus, and the plasmosome is undergoing disintegration. If, as is quite likely, there is a preliminary syndesis that synchronises with the synaptic contraction in the young oocyte, this stage may be interpreted as that of diakinesis. It is followed by an end-to-end pairing of the chromosomes. In sections of the egg-mass taken from newly-hatched flies at the beginning of April the chromosomes of the oocyte nucleus exhibited a considerably increased staining capacity, at the same time assuming a rod-like appearance. Later they approximate, each with one tip in contact with that of another (fig. 1, *3*). It was possible to count the pairs so formed, ten

FIG. 2.



Illustrating maturation phenomena in *Neuroterus*.

a, b, c, d. The maturation figures (after Doncaster).
e, f, g, h, i. Suggested interpretation of the maturation prophases

being present. At first these chromosome pairs are scattered irregularly; but subsequently they take up a definite arrangement, which is in all respects like the metaphase of a mitotic figure. They place themselves in a parallel series around a central axis with the point of contact of each conjugant indicated by a constriction in the equatorial plane. The chromosome complex so formed then condenses to form the oval compact nucleus, which is described by Doncaster in the eggs after they have been deposited (fig. 1, *4*, *5*, *6*).

Hegner has given full details of similar phenomena, as already mentioned, in *Copidosoma*; and on most points his account agrees closely with that given above for *Neuroterus*. In the former, according to Hegner, "the spireme becomes more and more open, and finally breaks up into thin chromosomes of irregular shape. These chromosomes then become shorter and thicker, and appear to unite near their ends. At first the pairs are scattered about in the nucleus, but they soon straighten out and become arranged in a parallel series with their points of union lying in the equator. Spindle fibres could be seen, but apparently no centrosomes nor asters are present. . . . The mitotic figure then passes through the stage of condensation. . . . The chromosomes gradually get closer together and become shorter and thicker. Where these ends meet at the equator a ridge appears which causes the complex to resemble a Maltese cross. Soon the spaces between the chromosomes are entirely obliterated and a homogeneous mass of chromatin results." Elsewhere Hegner refers to the arrangement of the chromosome pairs on a "Maturation spindle" in *Apanteles*, and in *Andricus*, the Oak-knot Gall-fly closely allied to *Neuroterus*. In *Neuroterus* the junction of the conjugating chromosomes is not indicated, as in these, by a thickening, but a constriction.

General Remarks.

In a postscript to his final memoir on gametogenesis in *Neuroterus*, added on receipt of Hegner's 'Protoplasmic Differentiation in the Oocytes of certain Hymenoptera,' Doncaster expressed the belief that the top-shaped nucleus, described by him in certain ova prior to maturation, is a stage in the disentangling of a compact nucleus formed in some such manner as in *Copidosoma*. This has been shown to be the case. The polar mitosis described by Doncaster represents the type of figure that might be predicted if the preparation for the homotypic split begins during the first division and extends from the junction of the conjugants to their free distal ends. The double threads drawn out in the formation of the first polar body from the reticulum so formed would be equivalent to univalent chromosomes precociously and incompletely split. The formation of the second body then consists presumably in separating the two halves.

If this interpretation prove to be correct, the separation of the polar chromosome groups in *Neuroterus* is the completion of a mitotic process that begins in the oocyte before it is laid. The maturation spindle in the late oocyte is a precocious and interrupted metaphase, preceded by an end-to-end pairing of univalents, and only differing from the normal type in consequence of its previous history and in the absence of asters or centrosomes. According to Doncaster, however, there are neither asters nor centrosomes in the polar and segmentation mitoses of the Saw-flies. In this case the solid and top-shaped nuclei of the full-grown egg in *Neuroterus* are not nuclei in the strict sense of the word. The only account, as far as I am aware, of a comparable prolongation of the maturation process is that of *Histriobdella*, where Shearer describes a protracted prophase lasting for a week while the cytoplasm of the egg was still in its growing phase.

It follows that in those Hymenoptera where similar maturation spindles have been described in the late oocyte, irregular methods for the extrusion of polar nuclei should prevail also. This appears to be the case in Martin's account of *Agehiaspis*, though details are lacking. Gatenby has described the formation of polar bodies in the Chalcid *Trichogramma* by what he terms "amitosis." It is, of course, of immense importance from the standpoint of the chromosome hypothesis to know whether amitosis occurs in germ nuclei; and if it is accepted that the nucleus of the full-grown egg in the parasitic Hymenoptera is in reality a condensed equatorial plate, an apparent constriction, simulating amitosis, does not imply an unequal distribution of chromatic elements, seeing that these are definitely orientated lengthwise in the complex. I have no hesitation in saying that the formation of polar bodies in *Trichogramma* cannot be justifiably contended to detract from the accepted views as regards the persistent individuality of the chromosomes.

Mention has been made of Henking's description of the maturation of the egg in *Rhodites*, the solid nucleus of which is reminiscent of that of *Neuroterus*, the separation of the polar chromosomes being also similar. A comparison of Schleip's figures of the chromosomes in the late oocyte with the same stage in *Andricus*, as shown by Hegner's plates, suggests very forcibly that they are in reality doubles and not univalent as Schleip believed*. I must, however, refrain from further comment on this head, seeing that I hope shortly to publish a full account of the chromosome cycle in this form.

I have to thank Dr. Doncaster for providing me with material for these observations, as well as for advice.

June 1919.

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* I have since found that such is actually the case.

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Notes upon the Reproduction of *Asellus aquaticus*. By ERNEST E. UNWIN, M.Sc. (Leeds). (Communicated by the Rev. T. R. R. STEBBING, M.A., F.R.S., F.L.S.)

(PLATES 25, 26.)

[Read 5th June, 1919.]

INTRODUCTION.

SOME years ago when beginning an enquiry into the life and structure of the terrestrial Isopoda, I started a general examination of the order; and the fact that *Asellus aquaticus* was common in all ponds and streams and easily kept in captivity, led me to spend not a little time upon its life and structure. I have kept it more or less under observation since.

Many investigators have paid attention to this fresh-water isopod. Leydig, Schneider, Rosenstadt, Kimus, and more recently Wege and Kaulbersz, have published valuable papers *. Kimus deals exclusively with the structure of the branchial pleopods in a comparative study of the branchiæ of aquatic isopods. Wege uses *Asellus* for experiments upon regeneration of appendages. Kaulbersz, in a long and interesting paper, describes a large number of experiments dealing with the behaviour of *Asellus* under varying conditions of light and chemical stimuli, as well as some notes upon regeneration, reproduction, and moulting.

The notes which follow are a contribution to a fuller knowledge of reproduction in the Isopoda.

REPRODUCTION.

There is an intimate relation between the processes of reproduction and the change of cuticle. Both copulation and egg-laying are heralded by the ecdysis of the female cuticle. It will be best, therefore, to describe this in brief. The cuticle is always cast in two pieces: first of all the hind-half and then, after a short interval, the fore-half. This interval has usually been about 24 hours, but I have records varying from 8 hours to 3 days.

Both Kaulbersz and Wege confirm the normal interval; the latter writer has compiled an elaborate table in which a day is the usual interval, and he mentions that the normal time is from 12 to 24 hours.

The splitting is always between the 4th and 5th thoracic segments. I have examined a large number of cast cuticles and have not, as yet, found an exception to this.

* See "Bibliography," p. 342.

The old cuticle is split transversely in the thin cuticle joining the terga of the 4th and 5th segments, and then quickly the split extends laterally and ventrally. The creature holding firmly on to the weed with the first 4 pairs of legs sways the hinder part of its body up and down. This action seems to help in the withdrawal of the legs and other appendages from the old cuticle. I have also noticed that the casting of the hind part is assisted by slowly walking forwards a short distance; the friction of the legs of the old cuticle against the weed of the ground helps the withdrawal.

I have not been able to detect any other splitting; each half is a perfect cast of the part of the body from which it comes. *Asellus* does not, as a rule, eat its cast cuticle. This is the usual procedure in the Oniscoidea.

Both Wege and Kaulbersz give tables of the interval between two successive moultings, and discuss the effect of various factors, such as food, age, temperature, mutilation, upon this interval. With poor food the intervals average about 24 days; Wege has records varying from 8 to 30 days. The average time under normal conditions is about 3 weeks. The moulting in relation to the sexual processes will be discussed below.

The sexes are distinct. Full-grown males are much larger than sexually mature females. With a lens the males can be readily distinguished by the presence of the modified pleopods (second). During the summer some females proclaim their sex by the presence of a brood-pouch containing developing eggs or young *Aselli*. I have records of egg-laying showing considerable variation; the earliest date on which I have captured a female with eggs in the brood-pouch is January 24th, and if the weather is fairly mild they can be found in this condition as late as the end of November. In the North of England from April to June is the most active period for reproduction.

Male. There are three pairs of testes lying in the middle region of the thorax. Each testis is an ovoid body attached by a very short duct to the vas deferens of its side. The two vasa deferentia, fairly thick tubes, extend from about the 3rd or 4th segment to the 7th. Each opens separately by a spout-like aperture, which, protruding from the last thoracic segment, lies just in front of the small rudimentary first pleopods (Pl. 25. fig. 6). They will discharge in the immediate vicinity of the second pair of pleopods. These appendages (Pl. 25. fig. 7) are modified for the purpose of passing the mass of spermatozoa to the female. The structure can be seen from the figure. It is the endopodite which is specially modified, forming something of a tube. The general shape is triangular, and its attachment to the protopodite allows great freedom of movement. The distal end is knob-like, with a pointed recurved process not far from the end.

The fourth pair of walking-legs are accessory organs. They will be described later.

Female. The ovaries are paired and lie dorsal to the alimentary canal and hepatic cæca. In an immature specimen they are small and show little sign of eggs; but in a female about to lay eggs, the ovaries are very large and conspicuous, extending the length of the thorax, and have the form of thin-walled bags packed with spherical eggs. The external openings of the oviducts can only be seen at a particular period. When the female has passed through the ecdysis which releases the oostegites, the openings can be seen on the ventral surface at the base of the fifth pair of legs. They are narrow slit-like openings with thickened lips. By means of serial sections through specimens about to lay eggs after being released from the marriage-clasp, I found that these apertures lead into a fairly large spherical cavity in which a mass of spermatozoa could be seen. It is clear that these cavities function as receptacula seminis. They appear to be lined with chitin and communicate with the ovary of the corresponding side (Pl. **26.** fig. 12).

Marriage-clasp and fertilization.—It is a very common thing to find specimens of *Asellus* in the spring and early summer in pairs, a larger one above carrying a smaller one. These couples are always male and female—male above, female beneath. This is the marriage-clasp, and the larger male always holds the female by a special pair of legs, the 4th pair, which are smaller and slightly modified for this purpose. The 7 pairs of legs normally increase in size from before backward; but in a mature male this middle pair is an exception to this (Pl. **25.** fig. 3).

The three distal segments are modified to form a hook. The carpopodite, with a flattened surface fringed by special spines, is the dorsal arm of the hook, and grips the dorsal surface of the female's thorax. The propodite and the dactylopodite act as the ventral arm of the hook, which bends round the edge of the tergum and grips the ventral surface. The gripping surface of these two segments is similarly flattened and roughened with spines. Each of the legs is able to bend inwards at the joint between the basipodite and the ischiopodite (Pl. **25.** fig. 3); this gives the legs a **Z**-like arrangement, and the female can be slung in the space between the ventral surface of the thorax and the legs of the male. By varying the angle between the basipodite and the ischiopodite, the female can be raised or lowered for locomotion or feeding. Kaulbersz does not mention these legs. The position of hooking is not quite constant, but is usually near the middle of the thorax.

The female does not seem to mind the inconveniences of her position, but resigns herself to the inevitable. When the male walks forward slowly, she walks as well; but if he is moving rapidly, she allows herself to be dragged along. In this case she bends her head and fore-part of the thorax downwards so as to present her rounded back to the rush of water and to the obstacles that may be in the way. When the male stops she lifts her head and continues her feeding and breathing actions. The male is not inconvenienced by the presence of the female, as his larger size enables him to reach forward in front of the female for food.

If a male and female are put together in a dish of water, the process of capture and hooking can be easily watched. When they meet, the male quickly seizes the female; sometimes he has a long chase before he can secure her. Kaulbersz gives some observations, noting that if several males are present there are fights for the female, and that yellow-coloured males usually come out victorious. The female is secured by the 1st pair of legs, which are prehensile. In the male these legs are especially large and powerful (Pl. **25.** fig. 2). The figure shows the modification. The propodite is much enlarged, forming one side of the claw, and containing the powerful muscles for working the dactylopodite down upon it. Both of the segments have the opposable faces roughened with spines, and, in addition, there is a process carrying a few large spines near the proximal end of the propodite. The carpopodite is very much reduced.

When the male grasps the female, he turns her quickly over, as though inspecting her condition. If she has been impregnated already, or has the brood-pouch developed, he releases her at once; if she is in the right condition, he quickly turns her about until he can hook his 4th pair of legs over the edges of her thorax. I do not find that he prefers to lie on his right side as Kaulbersz suggests; indeed, he more often lies on his back so as to bring all his legs into use. Having secured the female, the male rights himself and walks off with the female slung beneath.

The real meaning of this association of male and female has become clear by a number of observations made in the spring of 1908 and verified several times since. Most observers refer to this association and to the varying times of its duration; but they have not appreciated the real significance of it or the reason for the longer or shorter time of association in this marriage-clasp.

The length of the period of association depends upon the nearness of the next female ecdysis. Impregnation and egg-laying cannot take place until a change of cuticle releases the large oostegites for the brood-pouch and exposes the external openings of the oviduct. It is the casting of the hind-half of the female cuticle which gives the signal for the attentions of the male, and this casting is always accomplished before copulation. If one thinks of the short time which elapses between the casting of the cuticle and egg-laying, as well as the delicate condition of the creature at the time, it will be obvious that the association is of real value. The chance of male and female not meeting at the right time, and the fact that in all probability the female would be in hiding, makes this marriage-clasp most important.

When the ecdysis is about to take place, the male gives his attention to the female, and seems to assist her in working off the hind-half by walking slowly forwards a few steps and by holding her in such a position that the waving motion can be performed with ease. When the cuticle is cast, the female is ready for the attentions of the male. He need not wait until the fore-part is cast, for the oviducal openings are on the 5th thoracic segment, and this segment is exposed by the casting of the hind-half. The male now adjusts the position of the female so that her 5th thoracic segment is immediately below his 2nd pleopod. Kaulbersz mentions that the impregnation takes place with the creatures belly to belly. I have never seen this. All that I could see of this operation was a sideways sliding of the body of the male, so that the ventral surface of his body pressed against the side of the female's thorax. It looked almost like a hugging of the female, and the arrangement would certainly bring the 2nd abdominal appendages into the immediate neighbourhood of the female reproductive openings. After occupying this position for some time on one side, he changed sides and the operation was repeated. I have kept couples under observation during the whole of this period, that is to say from the casting of the hind-half to the release of the female, and have never seen the two individuals with ventral surfaces opposed. The length of this active copulation period varies somewhat. In one case it only lasted an hour. The hind-half of the female's cuticle was finally cast free at 8.30 P.M. after two hours being spent on this operation. The male waited about 20 minutes before beginning copulation, and this was completed and the female released by 9.30 P.M. This was the shortest time recorded, the average being from 2 to 3 hours. In one case it lasted 5 hours.

After separation from the male, the females had a mass of spermatozoa in the expanded receptacles just within the openings on the 5th thoracic segment. I have verified this by dissection and by paraffin sections (Pl. **26**. fig. 12).

The female is now released, as the purpose of her long association with the male has been achieved; and she seeks some convenient hiding-place, under a leaf or stone or in a hollow stem, to await the completion of her ecdysis, and with it the release of the oostegites. This completion of the ecdysis takes place usually about 24 hours after the first part, but I have a record of 8 hours only.

The oostegites are now released. Up to this they have been represented by small club-like processes; but if one of these is examined, the much larger plate-like oostegite is seen folded up within, like a leaf in a bud waiting for its release at the time of ecdysis. Each oostegite is a large free oval plate, overlapping its neighbours and its fellow of the other side to form a very safe brood-pouch for the reception of the eggs.

The first 4 pairs of legs carry these oostegites attached to the coxopodites. The general structure can be seen by reference to Pl. 26. figs. 10 & 11. It is interesting to find that the detailed structure of the oostegites is very like that of the branchial plates. Both surface observations of living oostegites and transverse sections of fixed material reveal a very similar arrangement to that found in the 4th pair of pleopods. It is easy to see in living specimens the flow of blood through the oostegites, and they show blood-spaces and "pillars" of much the same structure as those described by Kimus in connection with the branchiæ of *Asellus*. When the oostegites are released, the next operation is the passage of the eggs from the ovary to the exterior by way of the very short oviduct and receptaculum seminis. The fertilization probably takes place at this time, and the eggs are passed out through the aperture at the base of the 5th pair of legs and conducted into the brood-pouch. The 4th pair of oostegites can, by a slight bending of the body, be made to overlap the apertures through which the eggs are passed out. In this way, and by the help of the last two pairs of thoracic legs, the eggs are passed into the brood-pouch.

This operation does not take place directly the brood-pouch is available; a period of from 5 to 12 hours elapses before the brood-pouch is filled with the eggs.

The number of eggs laid at a time varies somewhat, the smallest number which I have found being 39 and the greatest 62; the average of many specimens is 46.

The succession of events can now be summarized:—

1. Male and female in association until the hind-half of the female cuticle has been cast.
2. Impregnation of the female by the male.
3. Female released by the male from the marriage-clasp.
4. Fore-half of the female cuticle cast; the oostegites are released thereby.
5. Fertilization and passage of eggs into the brood-pouch.

Development period.—The eggs are well supplied with yolk, and the whole of the development takes places inside the brood-pouch, which is, as we have seen, external to the body and contained between the ventral body-wall and the overlapping oostegites. The problem of a constant supply of fresh water is solved in several ways.

The movement of the legs in walking will cause a certain amount of movement of the oostegites and thus cause a slight changing of the water;

but there are definite and very effective methods of doing this. The first one to be noted is the lowering and raising of the oostegites themselves. The plates slowly lower a little way. The appearance is as though the brood-pouch was swelling. Then the plates return rather quickly to the normal position. A considerable change of water is caused by this method, and the eggs are seen to shake about during the operation. If the animal is undisturbed, this operation may be repeated about 8 times a minute for 10 minutes or longer; and then a period of rest before restarting another set of pulsations. By the use of powdered carmine the effectiveness of the method was easily demonstrated, and it was clear that the flow of water was from behind forwards. The carmine was sucked in at the hinder end of the pouch and, after several movements of the plates, was entirely removed.

The 1st pair of legs is carried bent inwards at the joint between the basipodite and the ischiopodite, to form two elbows which repeatedly jerked backwards into the brood-pouch whilst the plates were being lowered and raised. By fastening the legs so that they could not do this, I found that they acted as guards at the exit of the brood-pouch. By their action they prevent eggs escaping with the outgoing rush of water. Quite a number of eggs escaped whilst the legs were not in action, but under normal conditions I have never seen them escape (Pls. **25** & **26**. figs. 2 & 10).

There is a further method of changing the water in the brood-pouch. It is a less vigorous method than the one just described, and is not seen during the movements of the oostegites. It is in the periods of rest between the pulsations of the brood-pouch that the flapping movements of the maxillipedes are noticed. The maxillipedes are broad and plate-like, and are situated just in front of the 1st pair of oostegites. By their flapping movement they draw a steady stream of water through the brood-pouch. Pl. **25**. fig. 5 shows one of these maxillipedes taken from a female with a brood-pouch packed with eggs. If it is compared with a maxillipede of a non-egg-carrying female or of a male (Pl. **25**. fig. 4), it will be seen that a coxal lobe is present. This lobe is covered with feathered setæ and projects a little way into the brood-pouch (Pl. **26**. fig. 10). The addition of this feathered lobe will make the maxillipede more effective as a current producer; but their position and structure make them effective guards against the escape of eggs during this operation. The 1st pair of legs only come into action during the more vigorous method.

This coxal lobe is only found on the maxillipedes of a female with brood-pouch. In a female taken from the marriage-clasp, and about to cast the cuticle, the new chitinous cuticle, with the coxal lobe, could be seen under the old cuticle of a normal maxillipede, ready to be pushed out when the old cuticle was cast.

The eggs take about a month in their development. The tiny *Aselli* remain for some days in the brood-pouch, eating the débris and generally getting used to life before struggling out of the pouch at the hinder end. There is no general escape of the young; they push out by twos and threes, and even after a week or ten days one or two young *Aselli* can be found in the pouch.

Here are three typical periods of development:—

Eggs laid	Feb. 18th;	young escaping	Mar. 20th.
„ „	Mar. 7th;	„ „	Apr. 7th.
„ „	Mar. 28th;	„ „	May 1st.

Soon after the escape of the young, the female passes through another ecdysis and returns to the condition similar to that of the normal female. The large oostegites are replaced by small processes.

Note upon a variation of the 1*st pleopod of the female.*—In Pl. **25**. fig. 9 is shown a curious variation of the 1st abdominal appendage. The normal one is seen in Pl. **25**. fig. 8. It approximates to the 2nd abdominal appendage of the male (Pl. **25**. fig. 7). I discovered it whilst watching the circulation of blood in the oostegites of a living female with eggs. The unusual appearance of the appendage attracted my attention. I examined at once every available female, 35 in number, but did not find another with any such variation.

ERNEST EWART UNWIN.

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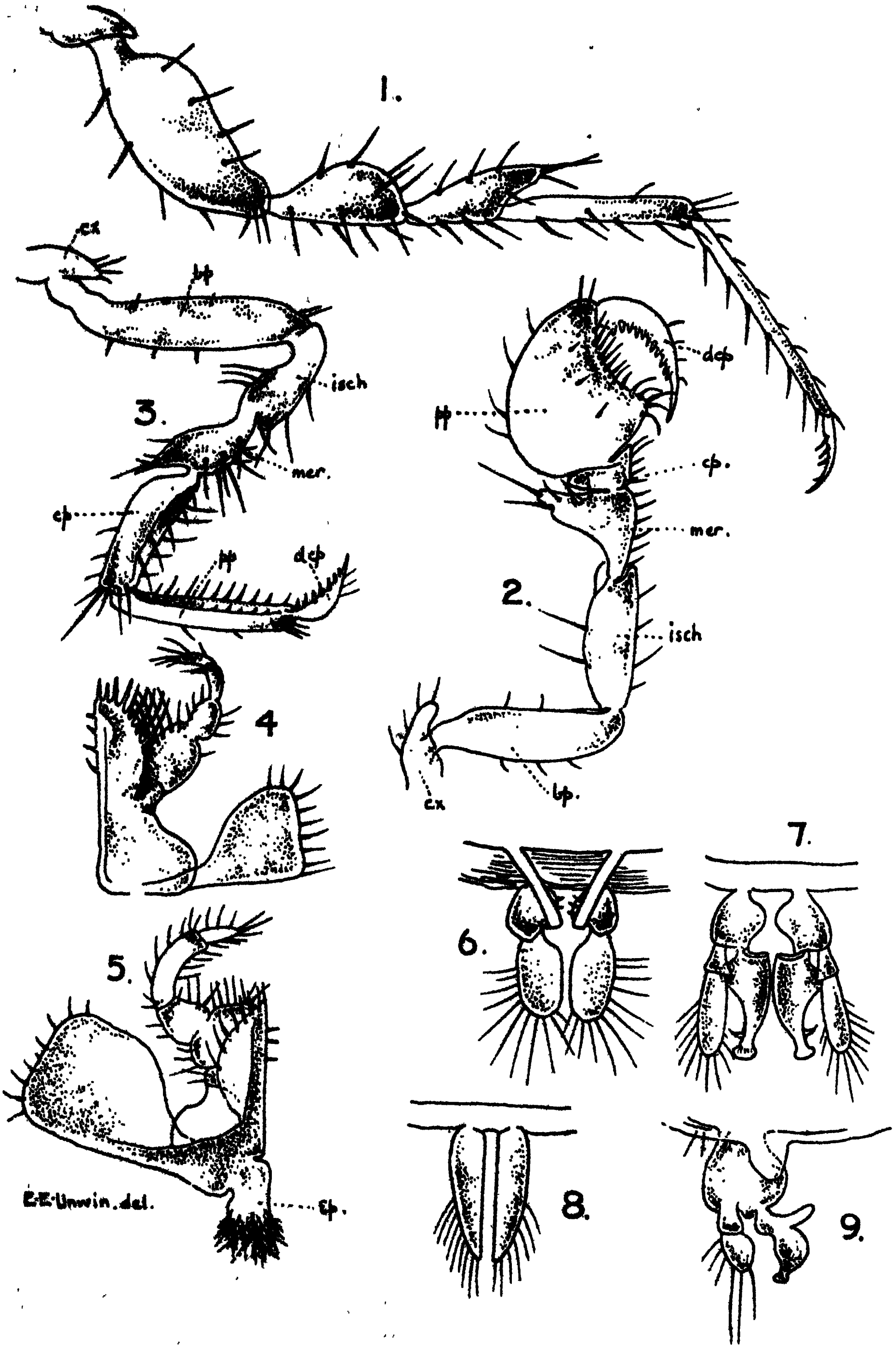
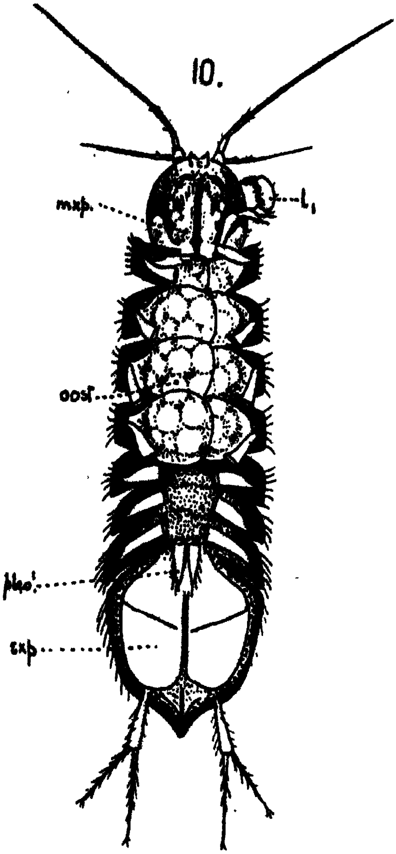
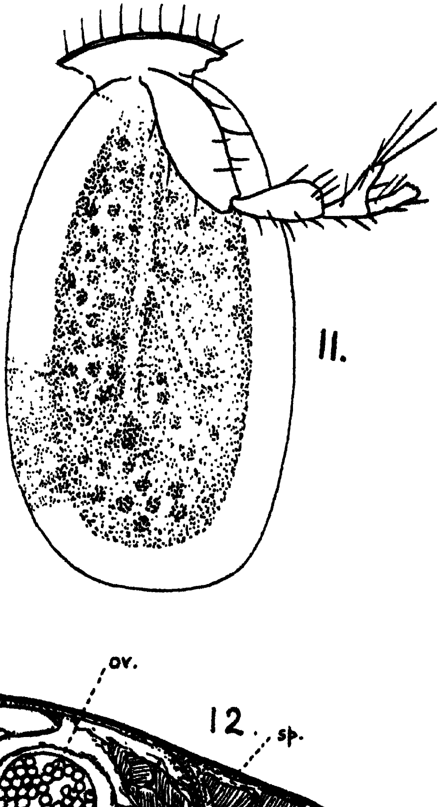


ASELLUS AQUATICUS.

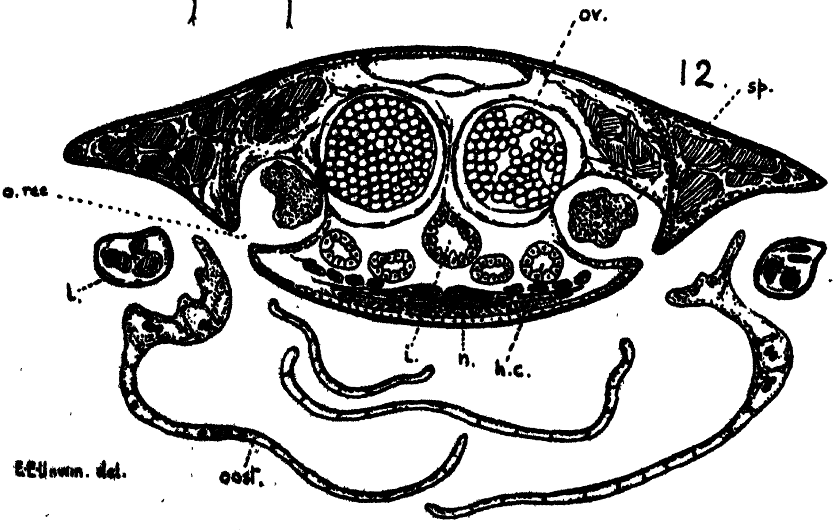
10.



11.



12



E.E.Unwin. del.

ASELLUS AQUATICUS.

EXPLANATION OF THE PLATES.

PLATE 25.

Fig. 1. Last thoracic leg (7th), for comparison with the specialised legs in Pl. **25**. figs. 2 & 3. × 30.
Fig. 2. 1st thoracic leg of ♂. × 30.
Fig. 3. 4th „ „ „ × 30.
Fig. 4. Maxillipede of a female during the non-reproductive stages. × 30.
Fig. 5. „ „ „ „ „ brood-pouch stage. × 30. (Notice the coxal lobe *ep.*)
Fig. 6. 1st abdominal appendages of ♂ with the spout-like terminations of the vasa deferentia. × 30.
Fig. 7. 2nd abdominal appendages of ♂. × 30.
Fig. 8. 1st abdominal appendages of ♀. × 30.
Fig. 9. Variation of 1st abdominal appendage of ♀. × 30.

PLATE 26.

Fig. 10. Ventral view of female. × 10. All the thoracic legs, except the 1st left, have been cut off.
Fig. 11. An oostegite, ventral view. × 40. A part of the leg is omitted.
Fig. 12. Transverse section through the 5th thoracic segment of ♀ taken after impregnation by the male but before the eggs were laid. × 40.

References.

cx.	coxopodite.
bp.	basipodite.
isch.	ischiopodite.
mer.	meropodite.
cp.	carpopodite.
pp.	propodite.
dcp.	dactylopodite.
ep.	coxal lobe.
l.	leg in T. S.
oost.	oostegite in section.
i.	intestine.
n.	nerve-cord.
hc.	hepatic cæcum.

mxp.	maxilliped.
l_1.	1st thoracic leg.
oost.	oostegite.
pleo^1.	1st abdominal appendage.
exp.	exopodite of the 3rd abdom. appendage. It acts as an operculum for the other branchiæ.
ov.	ovary. Egg, full size, ready to be passed out.
sp.	mass of spermatozoa in the receptaculum seminis.
o. rec.	aperture for entrance of sperm-mass and for escape of eggs.

Report on the Stomatopoda and Macrurous Decapoda collected by Mr. Cyril Crossland in the Sudanese Red Sea. By WALTER M. TATTERSALL, D.Sc. (Vict.), Keeper of the Manchester Museum. (Communicated by W. A. HERDMAN, F.R.S., F.L.S.)

(PLATES 27, 28.)

[Read 19th June, 1919.]

THE collections of Stomatopoda and Macrurous Decapoda collected by Mr. Crossland in the Sudanese Red Sea were kindly entrusted to me for examination and report by Professor W. A. Herdman, to whom I desire to express my thanks for the opportunity of examining so interesting a collection. The latter comprises 10 species and varieties of Stomatopoda, and 60 species and varieties of Macrurous Decapoda, 8 of which, viz., 1 *Athanas*, 2 *Alpheus*, 4 *Periclimenes*, and 1 *Nikoides*, I have been unable to determine specifically owing to the defective nature and small number of the specimens. Four species are described as new to science—*Athanas crosslandi*, *Synalpheus quinquedens*, *Periclimenes calmani*, and *Upogebia pseudochelata*, and a further twelve species are new to the fauna of the Red Sea. These latter are *Penæopsis stridulans* (W.-M.), *Eusicyonia carinata* (Oliv.), *Athanas parvus*, De Man, *Synalpheus streptodactylus*, Cout., *Synalpheus hululensis*, Cout., *Alpheus bucephaloides*, Nobili, *Alpheus consobrinus*, De Man, *Harpilius depressus* (Stimpson), *Harpilius gerlachei*, Nobili, *Anchistus inermis*, Miers, *Leander concinnus* (Dana), and *Gonodactylus pulchellus*, Miers.

Among the more interesting points brought out by the material in the collection are :—

The material of *Gonodactylus demani* and its variety *spinosus* suggests that these two forms are constantly distinguished by characters which may ultimately be considered of specific value.

Gonodactylus brevisquamatus, Paulson is represented by nine specimens, and my observations lend support to Mr. Patience's view that *G. fimbriatus* of Lenz is synonymous with Paulson's species.

I am able to supplement Nobili's descriptions and figures of *Penæopsis stebbingi* and *P. vaillanti* in some few points.

My observations on the species of the genus *Athanas* have led me to suggest a slightly different explanation of the so-called "trimorphism" discovered by Kemp in *A. polymorphus* and to show that dimorphism among males is exhibited by at least three species of the genus.

The re-discovery of *Synalpheus savignyi*, Guér., apparently lost sight of for nearly a hundred years, is a point of some interest.

I have suggested that *Pontonia pinnæ*, Ortmann, is a synonym of the earlier described *Anchistus inermis* (Miers).

The examination of the single specimen of *Leander tenuicornis*, Say (=*L. natator*, M.-Ed.) emphasises the necessity of a revision of the genus, with special reference to the number of joints in the mandibular palp and its value as a generic character.

The most recent complete list of Red Sea Crustacea is contained in Nobili's work "Fauna carcinologique de la Mer Rouge," where 142 species of Macrurous Decapoda and 16 species of Stomatopoda are enumerated. Of the Stomatopoda, *Gonodactylus graphurus* is considered by Kemp as a doubtful record, leaving 15 species of this group as members of the Red Sea Fauna, to which the present collection makes no additions beyond recording *Gonodactylus pulchellus*, Miers, definitely from within the Rea Sea proper, this species appearing in Nobili's list on specimens from Aden.

Nobili's list of Macrurous Decapoda omitted the following species recorded by earlier writers :—

(1) *Synalpheus savignyi*, the name given by Guérin to the *Athanas nitescens* of Audouin and Savigny's great work.

(2) *Pterocaris typica* and *Lysmata trisetacea*, both described by Heller from Red Sea specimens.

(3) *Penæopsis velutinus*, Dana, recorded by Paulson in 1875.

(4) *Parabetæus culliereti*, recorded by Coutière (1897 *a*).

(5) *Alpheus djeddensis*, Cout., and *A. macrodactylus*, Ortm., recorded by Coutière (1897 *e*), and *A. malleodigitus* (Sp. Bate) by the same author (1899).

Since Nobili's paper appeared the following additions to the Red Sea fauna have been made :—

(1) Coutière in 1909 added *Synalpheus heroni*, Cout., and in 1910, *Saron neglectus*, De Man; (2) De Man in 1909 *b* added *Alpheus djiboutensis*, Cout.; and (3) Balss (1914 *a* & *b*) recorded the following eight additional species:—*Haliporus steindachneri*, Balss, *Parapenæus fissurus* (Sp. Bate), *Parapandalus pristis* (Risso) and *P. adensameri*, Balss, *Dorodotes levicarina*, Sp. Bate, *Ægeon pennatus*, Sp. Bate, *Stenopus spinosus* (Risso), and *Paratypton siebenrocki*, Balss. Admitting the validity of all the old records and with the addition of the 11 species herein recorded for the first time from the Red Sea, and the four new species described below, the total number of Macrurous Decapoda now known from the Red Sea amounts to 176, an increase of 34 on Nobili's total.

The Red Sea in the past has received a considerable amount of attention at the hands of carcinologists, with the result that no fewer than 60 out of the 176 species (35 per cent.) of Macrurous Decapoda known from its waters have so far not been met with outside that area. In attempting to make a comparison of the species found in the Red Sea with those found in other parts of the Indian and Pacific Oceans, such as has been done by Laurie (1915) for the Brachyura, it at once becomes evident that our knowledge of the Macrurous Decapoda of the Indo-Pacific region is not nearly so complete as it is for the Brachyura. The enquiry is complicated by the intricate synonymy of various species particularly among the Penæidæ and the Alpheidæ, so that an exact knowledge of the distribution of many of the species is not easily come by. The general results which have emerged from my enquiry as to the distribution of the species found in the Red Sea may be stated as follows :—

Persian Gulf. Nobili, 1906 *b*.

26 Red Sea species are recorded in this report from various stations in the Persian Gulf and Arabian Sea =15 per cent. of the total Red Sea species.

Maldive and Laccadive Archipelago. Coutière, 1905.

A comparison between the whole of the Macrura of the Red Sea with those of the Maldives is not possible, but the Alpheidæ of the latter locality have been thoroughly worked by Coutière and afford material for a comparison. 35 out of the 69 species of the Red Sea Alpheidæ or 50 per cent. have been recorded from the Maldive Archipelago.

Ceylon. Pearson, 1905 and 1911. Kemp, 1914.

27 out of 176 Red Sea species or 15·5 per cent. are included in Pearson's papers.

The Alpheidæ again afford a better basis for a comparison, 14 out of 69 Red Sea species, or 20 per cent., having been recorded from Ceylon.

India. Alcock, 1908. Henderson, 1893. Kemp, 1914 & 1915.

A total of 28 Red Sea species out of 176 or 16 per cent. have been recorded from the coasts of India.

The families of the Penæidæ and Hippolytidæ are perhaps the best known of the Indian Macrurous Decapods. Of the former (Alcock, 1906) 7 Red Sea species out of 19, or 37 per cent., are known from India, and of the latter (Kemp, 1914) 7 Red Sea species out of 12, or 58 per cent., are also Indian forms.

Malay Archipelago and Dutch East Indies. De Man, 1887, 1888, 1896–98, 1902, 1911 *a* & *b*.

The waters of this region of the Indo-Pacific have been more thoroughly explored than perhaps any other, and the comprehensive works of De Man afford material for a more exact comparison of the

Macrurous Decapoda of the Red Sea and the Malay Archipelago than is possible for any other region.

57 out of 176 Red Sea species, or 33 per cent., are known from the Malay Archipelago and its adjacent waters. This percentage agrees closely with that given by Laurie for the Brachyura of the Red Sea compared with the Seychelles, Maldive Archipelago, Ceylon, and the Hawaiian Isles.

The Siboga Reports on the Penæidæ and the Alpheidæ provide interesting results.

9 out of 19 Red Sea species of Penæidæ or 47·5 per cent., and 29 out of 69 Red Sea species of Alpheidæ or 42 per cent., were taken by the Siboga Expedition in the waters of the Dutch East Indies.

East Coast of Africa. Borradaile, 1910. Lenz, 1905 and 1910. Miers, 1884. Ortmann, 1894.

29 out of 176 Red Sea species, or 16·5 per cent., are known from this region.

It is obvious from those results that much remains to be done before the Macrurous Decapoda of the Indo-Pacific can be said to be fully known. So far as they go, they support Laurie's contention that the fauna of the Red Sea forms an integral part of the fauna of the Indo-Pacific Ocean.

To save frequent repetition I give a list of stations from which the present collection was made. It has been compiled to suit the present report, from Laurie (1915, p. 419). Crossland (1907) should be consulted for a detailed account of the collecting grounds.

I. Suez. Lat. 28° N.
  A. Suez mud-flats.
  B. Suez flats and docks. Dec. 1904.
  C. Suez mud-flats and dock walls, from yellow sponge.
  D. Suez, from among coral.
  E. Purchased, Nov. 1904.

II. Mersa Wadi Lehama, Egyptian coast. Lat. 24° 45′ N.

III. Mersa Abu Hamâma. Lat. 21° 30′ N. 12 fathoms. Mud.

IV. Khor Shinab. Lat. 21° 20′ N. 10–12 fathoms. Mud among sponges and Polyzoa.

V. Khor Dongonab. Lat. 21° 11′ N. to lat. 20° 50′ N.
  A. Washed from nullipore and branched coral from the reef off Beacon Island. Lat. 20° 55′ N. 26 April, 1905.
  B. Just west of Beacon Island. Lat. 20° 55′ N. Washed from nullipore dredged in 3–5 fathoms, 26 April, 1905.

C. Engineer Island. Lat. 20° 50′ N. Washed from old coral and weed obtained from Reef Flat.

D. Engineer Island. Lat. 20° 50′ N. Washed from weed and coral dredged in 3 fathoms of water.

E. Khor Dongonab. Among coral on reef.

F. North of the Barrier (see Crossland's map, p. 15), 20 fathoms. Mud.

G. Washed from ribbon-like sponge characteristic of the nullipore beds.

VI. Mersa Ar-rakiya. Lat. 20° 15′ N. Among coral in one fathom of water.

VII. Suakin Harbour. Lat. 19° 8′ N.

A. Suakin Harbour.

B. Suakin Harbour. 26 Jan., 1905.

C. Suakin Harbour. From coral, 1905.

D. From ascidians and barnacles of buoy moored in Suakin Harbour.

E. Washed from sponges.

F. „ „ „ 11 Jan., 1905.

G. Commensal in Black Pinna.

VIII. Shubuk. Lat. 18° 52′ N. to 18° 43′ N.

A. Mersa Makdah in Shab-ul-Shubuk.

B. We Shubuk, south-east corner. 16 Feb., 1905.

C. "Dredge washings, 17 Feb., 1905."

IX. Tella Tella Kebira, a small group of islands in the northern part of the Suakin Archipelago. Lat. 18° 48′ N.

A. Tella Tella Kebira. Washed from the half-loose coral fragments and nullipore which compose the edge of the Southern Reef. 3 March, 1905.

B. Tella Tella Kebira, From sand.

X. Trinkitat Harbour entrance. Lat. 18° 40′ N. 2 fathoms. Rock, weed, and nullipore.

XI. Agig. Lat. 18° 13′ N. From among coral in 4½ fathoms of water.

The distribution of the species in the present collection among the above stations is set forth in the following table, from which it will be seen that the coral reefs at Khor Dongonab and Suakin Harbour were by far the most productive in species.

	Station I. Suez. Lat. 28° N.	Station II. Mersa Wadi Lehama. Lat. 24° 45′ N.	Station III. Mersa Abu Hamâma. Lat. 21° 30′ N.	Station IV. Khor Shinab. Lat. 21° 20′ N.	Station V. Khor Dongonab. Lat. 21° 11′ N. to 20° 50′ N.	Station VI. Mersa Ar-rakiya. Lat. 20° 15′ N.	Station VII. Suakin Harbour. Lat. 19° 8′ N.	Station VIII. Shubuk. Lat. 18° 52′ N. to 18° 43′ N.	Station IX. Tella Tella Kebira. Lat. 18° 48′ N.	Station X. Trinkitat Harbour. Lat. 18° 40′ N.	Station XI. Agig. Lat. 18° 13′ N.	Locality indefinite. Lat. 28° N. to 18° 13′ N.
1. Penæopsis stebbingi (*Nobili*)	×	:	:	:	:	:	:	×	:	×	:	×
2. " stridulans (*W.-M.*)	:	:	:	:	:	:	:	×				
3. " vaillanti (*Nobili*)	:	:	:	:	:	:	:	×				
4. Trachypenæus anchoralis (*Sp. B.*)	:	:	:	:	:	:	:	×				
5. Penæus japonicus, *Sp. B.*	×	:	:	:	:	:	:	×				
6. " semisulcatus, *De Haan*	:	:	:	:	×							
7. Eusicyonia carinata (*Oliv.*)	×											
8. Athanas crosslandi, *Tattersall*	:	:	:	:	×							
9. " parvus, *De Man*	:	:	:	:	×	:	:	:	:	:	:	×
10. " dimorphus, *Ortmann*	×											
11. " sp.?	×											
12. " djiboutensis, *Cout.*	:	:	:	:	×	:	×	:	×			
13. Synalpheus gravieri, *Cout.*	:	:	×									
14. " streptodactylus, *Cout.*	:	:	:	×								
15. " triunguiculatus (*Paulson*)	:	:	:	:	×	:	×					
16. " fossor (*Paulson*)	:	:	:	:	:	:	:	×				
17. " heroni, *Cout.*	:	:	:	:	:	:	:	:	×			
18. " hululensis, *Cout.*	:	:	:	:	:	:	:	:	×			
19. " biunguiculatus (*Stimp.*)	:	:	:	:	×	:	:	:	:	×		
20. " savignyi (*Guérin*)	:	:	:	:	:	:	×					
21. " quinquedens, *Tattersall*	×	:	:	:	×	×	×	:	:	:	:	×
22. Alpheus gracilis, *Heller*	:	:	:	:	:	:	×	:	×			
23. " ventrosus, *H. M.-Ed.*	:	:	:	:	×	:	×					
24. " microstylus (*Sp. B.*)	:	:	:	:	×							
25. " alcyone. *De Man*	:	:	:	:	×							
26. " sp.?	:	:	:	:	×							
27. " bucephaloides (*Nobili*)	:	:	:	:	×	:	:	:	×			
28. " consobrinus, *De Man*	:	:	:	:	×	:	×	:	×			

29. „ pachychirus, *Stimp.*	..	..	..	..	..	..	..	..	×			
30. „ insignis, *Heller*	..	..	..	..	..	..	..	..	×			
31. „ paracrinitus, *Miers*	..	..	..	..	..	..	×					
32. „ Audouinii, *Cout.*	..	..	..	..	×							
33. „ strenuus, *Dana*	×	..	..	..	×	..	×					
34. „ bouvieri, *A. M.-Ed.*, var. hululensis, *Cout.*	..	..	..	..	×							
35. „ parvirostris, *Dana*	..	..	..	..	×	..	×	..	×			
36. „ sp.?	..	..	..	..	..	×						
37. Saron neglectus, *De Man*	..	..	..	..	..	..	..	..	×			
38. Thor paschalis (*Heller*)	..	..	..	..	×							
39. Hippolyte proteus (*Paulson*)	..	..	..	..	..	..	..	..	..	..	..	×
40. Periclimenes petitthouarsii (*Aud.*)	..	..	..	..	×	..	×	..	..	..	..	×
41. „ calmani, *Tattersall*	..	..	..	..	..	..	..	..	..	..	..	×
42. „ sp.?	..	..	..	..	×	..	×					
43. „ sp.?	..	..	..	..	..	..	×					
44. „ sp.?	..	..	..	..	..	..	..	..	..	..	..	×
45. „ sp.?	..	..	..	..	..	..	×					
46. Coralliocaris superba (*Dana*)	..	..	..	..	×							
47. „ lucina, *Nobili*	..	..	..	..	×							
48. Harpilius beaupresii (*Aud.*)	..	..	..	..	..	..	×					
49. „ depressus, *Stimp.*	..	..	..	..	..	..	×					
50. „ gerlachei, *Nobili*	..	..	..	..	×							
51. Anchistus miersii (*De Man*)	..	..	..	..	..	..	×	..	..	..	..	×
52. „ inermis (*Miers*)	..	..	..	..	..	..	×					
53. Conchodytes meleagrinæ, *Peters*	..	..	..	..	..	..	..	..	..	..	..	×
54. Palæmonella tenuipes, *Dana*	..	..	..	..	×	..	×					
55. Leander tenuicornis (*Say*)	..	×										
56. „ concinnus (*Dana*)	×											
57. Nikoides sp.?	..	..	..	..	..	..	..	×				
58. Axiopsis æthiopica, *Nobili*	..	..	..	..	×							
59. Upogebia pseudochelata, *Tattersall*	..	..	..	..	..	..	×					
60. „ savignyi (*Strahl*)	×	..	..	..	×	..	×	..	..	..	..	×
61. Squilla massavensis, *Koss.*	×											
62. Pseudosquilla ciliata (*Fabr.*)	..	×										
63. „ megalophthalma, *Bigelow*	..	..	..	..	.	..	..	..	×			
64. Lysiosquilla multifasciata, *W.-M.*	..	..	..	..	..	..	..	×				
65. Gonodactylus chiragra (*Fabr.*), var. smithii, *Pocock*	..	..	..	..	×	×						
66. „ demani, *Henderson*	..	..	..	..	..	×	×	×				
67. „ „ „ var. spinosus, *Bigelow*	..	..	..	..	×	..	..	..	..	..	×	
68. „ glaber, *Brooks*	×	..	..	..	×	..	×	..	..	..	×	×
69. „ brevisquamatus, *Paulson*	..	..	..	..	..	..	..	..	×			
70. „ pulchellus, *Miers*	..	..	..	..	..	..	..	×				

LIST OF LITERATURE.

The following list contains a complete bibliography of all papers as far as I have been able to discover, which deal in any way with material of Macrurous Decapoda and Stomatopoda from the Red Sea. As regards the Penæidæ and Alpheidæ, I have included in the synonymies of the species, as far as possible, references to De Man's Siboga reports, as the last authoritative pronouncement on these two families. In the same way Kemp's paper on the Hippolytidæ (1914) has been used for that family, and the same author's monograph on the Stomatopoda (1913) for that group of Crustacea, while Borradaile's monograph of the Pontoniinæ (1917) has been followed for that group.

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In the preparation of this report I am greatly indebted to Mr. Patience for kindly allowing me to see the manuscript of his forthcoming paper on the Stomatopods collected by Mr. J. J. Simpson in the Mergui Archipelago, with reference to *Gonodactylus brevisquamatus*, Paulson. The Rev. T. R. R. Stebbing has kindly allowed me to consult and retain for several months his copy of Paulson's rare work on the Crustacea of the Red Sea, and Dr. W. T. Calman has also given me great assistance in the loan of literature. To these gentlemen and to Professor Herdman, I desire to record my grateful thanks.

The types of the new species have been deposited in the British Museum. The remainder of the collection is housed in the Zoological Department of the University of Liverpool.

STOMATOPODA.

Genus SQUILLA, *J. C. Fabricius.*

SQUILLA MASSAVENSIS, *Kossmann*, 1880. *See* Kemp, 1913, p. 76.

Locality. Station I. E, 3 ♀, 216 mm.

Remarks. These specimens are considerably larger than any which have hitherto been recorded. Kossmann's type measured 140 mm., Kemp's largest specimen had a length of 108 mm., Nobili gives the length of one of his specimens as 134 mm., while Balss gives no size for those he examined. They agree very closely with the descriptions given by Balss and Kemp. The latter author, however, states that the anterior bifurcation of the median carina of the carapace was not present in any of the specimens he examined.

This feature can be distinctly traced in the specimens here dealt with, though the actual carinæ are almost obsolete. The three rows of tubercles on the telson are well developed.

Distribution. Red Sea (Kossman, Nobili, Balss); Gulf of Oman and Persian Gulf (Kemp).

Genus PSEUDOSQUILLA, *Dana*, 1852.

PSEUDOSQUILLA CILIATA (*Fabricius*). *See* Kemp, 1913, p. 96.

Locality. Station II, 1 ♂, 50 mm.

Remarks. This specimen is an absolutely typical example of the species, without a spine on the postero-lateral angle of the fourth abdominal segment, and having the inner spine of the bifurcate process of the uropod slightly longer than the outer.

Previously recorded from the Red Sea by Nobili, 1906, and Balss, 1910.

PSEUDOSQUILLA MEGALOPHTHALMA, *Bigelow*, 1894. *See* Kemp, 1913, p. 103. (Pl. **27.** figs. 1–3)

Locality. Station IX. B, 1 ♀, 30 mm.

Remarks. It is with a considerable amount of reserve that I refer this specimen to Bigelow's species. Compared with his description the following differences are to be noted:—

(1) The corneal axis of the eye (Pl. **27.** fig. 2) is only five-sixths of the peduncular axis. In Bigelow's specimen the corneal axis is considerably broader than the peduncular axis (11 to 8).

(2) The length of the rostrum (Pl. **27.** fig. 1) is only four-sevenths of the breadth. It is thus shorter than in Bigelow's specimen (where the proportions are 5 to 7), and, though it covers the ophthalmic segment, it leaves the whole of the eye itself exposed.

(3) The lateral margins of the eighth thoracic segment are provided with a well-marked notch. No mention of such a notch is made by Bigelow.

(4) There are only six spines (Pl. **27.** fig. 3) on the sixth abdominal segment, there being no trace of the small spines on the inner side of the intermediates mentioned by Bigelow.

(5) Only the fourth, fifth, and sixth segments of the abdomen have spines at the postero-lateral corners. In Bigelow's specimen, the second and third segments also had these spines.

There are eight carinæ on the dorsal surface of the telson (Pl. **27.** fig. 3), in addition to the median one. In the nomenclature used by Kemp, these carinæ are the submedian, intermediate, second lateral, and marginal, the first laterals being absent. If my identification of this specimen is correct, it supports Kemp's suggestion that the carinæ next the marginals in this species are homologous with the second laterals of his nomenclature. In the present specimen they are quite well marked and terminate in the lateral spines of the telson. The submedian carinæ of our specimen are interrupted at about their centre. This may be what Bigelow means in calling it serrated. I may also remark that between the submedian and intermediate spines of the telson there are two lobes on the left side but only one on the right. There are ten spines on the outer margin of the proximal joint of the exopod of the uropods, the last of which reaches the level of the apex of the distal joint. The outer spine of the bifurcate process of the uropods is slightly longer than the inner, the latter reaching the apex of the endopod of the uropods, the former reaching half-way down the distal joint of the exopods. The raptorial claws of this specimen agree with Bigelow's description in having the pectinations on the inner margin of the propodus confined to the proximal half of that margin. There are no traces of eye-spots on the carapace. The most serious differences from Bigelow's description presented by the present specimen are the characters of the eye and the number of spines on the sixth abdominal segment. The notch on the lateral margin of the eighth thoracic segment may have been overlooked, while the spiniform nature of the postero-lateral corners of the abdominal segments is a variable character. Nobili, in recording this species from the Red Sea, notes that in his specimens only the fourth, fifth, and sixth segments of the abdomen had spines at the postero-lateral corners. But in his specimens the inner and outer spines of the bifurcate process of the uropods were subequal. He makes no mention of the size of the eyes, and we must presume that the sixth abdominal segment bore eight spines. The nearest relative of this species is *P. oculata*, from which the present specimen is distinguished by the absence of a spine on the rostrum, and by the presence of second lateral carinæ on the telson instead of first laterals. On the whole, I prefer to leave the present specimen in the species to which I have referred it. More material of both sexes is required before it can be stated whether the differences I have pointed out between my specimen and Bigelow's description are constant enough to be of specific importance.

Since writing the above, I have received a copy of Mr. Kemp's paper "On a collection of Stomatopod Crustacea from the Philippine Islands," in which he gives some notes on a single specimen of *Pseudosquilla megalophthalma* which he examined from that locality. I am now certain that my specimen belongs to that species. Kemp's specimen agrees with the present one in characters 3, 4, and 5 given above as points of difference between my specimen and Bigelow's description. Kemp gives no measurements for the eye, and the rostrum of his specimen is longer in proportion to the breadth than in mine, but these differences are trifling. Unfortunately, the Red Sea specimen shows no traces of the distinctive coloration described by Kemp.

Distribution. Mauritius (Bigelow); Obock in the Red Sea, and Djibouti (Nobili); Philippine Islands (Kemp).

Genus LYSIOSQUILLA, *Dana*, 1852.

LYSIOSQUILLA MULTIFASCIATA, *Wood-Mason*, 1895. *See* Kemp, 1913, p. 122. (Pl. **28**. fig. 6.)

Locality. Station VIII. B, 1 ♂.

Remarks. The specimen is imperfect, the last two segments of the abdomen, and the telson having been broken off. Identification is, therefore, a matter of some uncertainty. The raptorial claw (Pl. **28**. fig. 6), however, has the characteristic form of *L. multifasciata* as described by Kemp. The dactylus bears five teeth, including the terminal one, of which the penultimate is short. The two lobes at the base of its external margin are very unequal, the proximal quite small, the distal very much expanded. The colour of the present specimen in alcohol is distinctive. The carapace shows three bands of dark colour, two anterior paler ones, almost fused, and a posterior one, well marked. The last three thoracic segments each has a single dark band, occupying the posterior half of the segment. The first four abdominal segments possess a single very dark transverse line in the centre third of their posterior border. Above this line and separated from it by a pale line is a rather indistinct broad dark band which does not quite reach the lateral margins. From the postero-lateral corners of this pale transverse band, on each side, there is a much darker band running to the lateral margins. These latter bands have the appearance of being the lateral portions of an interrupted band, the centre part of which is missing. There is a distinct break in contour where these very dark bands meet the centre paler band, suggesting that the latter represents an anterior and separate band of colour.

Previously recorded from the Red Sea by Nobili (1906).

Genus GONODACTYLUS, *Latreille*.

GONODACTYLUS CHIRAGRA (*Fabricius*). *See* Kemp, 1913, p. 155.

Localities. Station V., 1 ♀, 60 mm. Station VI., 1 ♂. 40 mm.

Remarks. Both these specimens are of the variety represented by *smithii*, except that the median carina of the telson of the male does not end in a spine but is obtusely rounded.

A widely distributed Indo-Pacific species recorded from the Red Sea by Miers, Kossmann, and Nobili.

GONODACTYLUS DEMANI, *Henderson*, 1893. *See* Kemp, 1913, p. 164, pl. 9. figs. 108–111.

Localities. Station VI., 1 ♀, 22 mm. Station VII. C, 1 ♀, 14 mm., 2 ♂, 14 and 19 mm. Station VIII. C, 2 ♀, 27 and 30 mm.

Remarks. All these specimens agree with Henderson's figure of the type-specimen (1893) in being without setæ on the inner margin of the inner uropod (except for three or four at the extreme proximal part).

In the arrangement and number of tubercles on the telson, they agree generally with that shown in Kemp's figure 109, that is, the tubercles are large and few, but they show evidence that the tubercles increase in number with age and, likewise, become more obtuse, as the following description of the tuberculation of each specimen will show.

♂, 14 mm.

Two median tubercles, one behind the other, on the median carina, one on each submedian carina, one on the carinæ of the submedian teeth, and one on the carinæ of the intermediate teeth. All the tubercles very acutely pointed and spiniform. Carinæ of the sixth abdominal segment likewise ending in sharply pointed spines.

♀, 14 mm.

As above, except that there are two tubercles on the carinæ of the intermediate teeth.

♂, 19 mm.

Three spinous tubercles, forming a well-marked trident at the distal end of the median carina, two tubercles on each submedian carina, two at the base of the submedian teeth, and three on the carinæ of the intermediate teeth. All the tubercles acutely spinous, as are also the carinæ of the sixth abdominal segment.

♀, 22 mm.

Three spinous tubercles, forming a trident, at the distal end of the median carina; anterior to them a smaller median spinous tubercle flanked by a very small obtuse tubercle on each side; two tubercles on each submedian carina, three at the base of the submedian teeth, and three on the carinæ of the intermediate teeth. All the tubercles and the carinæ on the sixth abdominal segment, acute but not so sharply pointed as in the smaller specimens.

♀, 27 mm.

Almost exactly the tuberculation of the last specimen but all the tubercles obtusely rounded. This specimen agrees very closely with Kemp's figure 109.

♀, 30 mm.

Like the last, but only two tubercles at the base of each submedian tooth. All the tubercles obtuse.

These six specimens, therefore, form a compact group agreeing in the unarmed inner margin of the inner uropods and having a tuberculation of the telson following a general plan though varying with age. I regard them as referable to the typical form of the species, though Henderson (1893) figures the spinules on the telson of the type as distinctly smaller and more acute than they are on the specimen of corresponding size in the present collection.

Previously recorded from the Red Sea by Nobili (1906).

GONODACTYLUS DEMANI, *Henderson*, 1893, *var.* SPINOSUS, *Bigelow*, 1893.
See Kemp, 1913, p. 165, pl. 9. fig. 112.

Localities. Station V. D, 1 ♂, 15 mm. Station XI., 2 ♀, 22 and 32 mm.

Remarks. The two specimens from Agig have the entire surface covered with small spinules, densely packed. The small specimen from Khor Dongonab has the telson very much of the form shown in Lenz (1905, fig. 12), except that there is only one row of spinules on the submedian teeth. In all three specimens the intermediate and lateral teeth of the telson appear to me to be as well developed as in the typical form of the species. All three agree in having the inner uropod armed with setæ all round. It is this last character which has led me to refer these specimens to the variety *spinosus* of *G. demani*. Bigelow (1894), when describing this form originally, made no mention of the form of the inner uropod, but Lenz, in the figure already quoted, shows the inner uropod invested with setæ on the entire margin. When Kemp wrote the main part of the text of his valuable monograph, all the specimens, with one exception, of *G. demani* and its varieties to which he had access had the inner uropod setose all round, and it was only later (Addendum, p. 198) after he had examined a number of specimens from the Gulf of Manaar, which all agreed in having the inner margin of the inner uropod unarmed, that he became aware of this character. In Henderson's figure of the type specimen the inner margin of the inner uropod is figured as unarmed, and it seems to me to be just possible that the var. *spinosus* may be constantly differentiated from the typical form by this character. If this is so, then *G. spinosus*, Lenz has been correctly determined and is not a synonym of *G. demani*, Henderson, as given by Kemp. As I have already remarked, the tubercles on the telson of the typical form appear to be fewer, larger, and more obtuse than in the variety, and it may subsequently be discovered that this type of tuberculation goes with the unarmed character of the inner uropod, to emphasise the distinction between the type and its variety. Kemp does not give the character of the inner uropod of the specimen from which his figure 109 was taken. This figure, as I have pointed out, gives the general arrangement of the tubercles on the telson of those specimens which I have referred to the type form, all of which agree in having unarmed inner margins to the inner uropods. In support of the generally accepted opinion that *G. demani* and *G. spinosus* are varieties of one species, I may observe that the copulatory organs on the first pleopod of the male specimen from Khor Dongonab, referred here to the variety *spinosus* agree in detail with those from one of the males from Suakin Harbour referred to the typical form.

This variety has been previously recorded from the Red Sea by Nobili (1906).

GONODACTYLUS GLABER, *Brooks*, em. *Henderson*, non *Kemp*, 1913, p. 182.

Localities. Station I. D, 1 ♀, 47 mm.
Station V. E, 20 ♂, 24–54 mm., 15 ♀, 24–58 mm.
Station VII. B, 1 ♀, 68 mm. Station XI., 1 ♀, 35 mm.
Station V. B, 1 ♂, 16 mm. Station V. C, 2 ♀, 9 and 11 mm.
Station V. D, 1 ♀, 30 mm. No locality, 1 ♀, 60 mm.

Remarks. This species is by far the commonest Stomatopod found in the Red Sea. All the specimens, except one listed above, may be referred to the var. *ternatensis*, De Man, and bear traces of the green colour characteristic of the majority of specimens of this species. The one exception, already noted, appears to be referable to the var. *rotundus* of Borradaile. The keels on the telson are broad and swollen so as to touch one another, but there are traces of spines on the three middle keels. This specimen shows no traces of the two black spots on the telson which form so constant a feature of this species, and its colour, as preserved, suggests a mottled or marbled light brown colour in life.

This species has been recorded from the Red Sea previously by Nobili and Balss.

GONODACTYLUS BREVISQUAMATUS, *Paulson*, 1875. (Pl. 27. figs. 5–6.)

G. brevisquamatus, Nobili, 1906*a*.
G. fimbriatus, Lenz, 1905.
G. fimbriatus, Borradaile, 1907.
G. fimbriatus, Lenz, 1910.
G. brevisquamutus and *G. fimbriatus*, Kemp, 1913.

Locality. Station IX. A, 5 ♂, 4 ♀, 13–28 mm.

Remarks. From Kemp's monograph I learnt that Mr. Patience had found a specimen of this species in a collection of Stomatopods from Mergui and, as a result of his researches, had come to the conclusion that *G. brevisquamatus*, Paulson and *G. fimbriatus*, Lenz are synonymous. On my writing to him, he very kindly allowed me to see the manuscript of his paper and, after comparing my specimens with his description, I can unhesitatingly support his view. There seems to me to be no doubt whatever that the two species are one and the same.

In the largest of my specimens the antennal scale reaches forward to the extremity of the eye, and is therefore relatively longer than shown in Paulson's figure, but in the smaller specimens the scale approaches much more nearly to the proportions shown by Paulson, and the size of the scale evidently increases with age.

On the sixth abdominal segment (Pl. **27.** fig. 6) the median carinæ are invariably wider than the intermediates. In the male the median carinæ are parallel, but in the female they are slightly divergent. All the carinæ on this segment are smooth and do not terminate in spines, though the lateral carinæ terminate more acutely than shown in Paulson's figure 3 *r*.

The telson (Pl. **27.** fig. 6) bears in the middle of the dorsal surface an oval smooth elevation terminating distally in young specimens in an obtuse slightly transverse tubercle. This tubercle becomes obsolete or almost so with growth; it is hardly discernible in the largest specimens. On each side of the median elevation there is a prominent submedian carina in close contact with the median one throughout its length. Lateral to the submedian again there is on each side a much fainter carina, distinct in its posterior half but merging into the submedian carina anteriorly. It presents the appearance of a half carina only. Lenz in his figure of the telson of *G. fimbriatus* figures *two* faint carinæ lateral to the submedians, but none of the present specimens show traces of more than one. The carinæ of the intermediate spines are well marked and smooth, while the lateral margin of the telson is thickened to form a ridge. There are two tubercles near the anterior margin of the telson, one on each side of the median elevation and homologous with those found in *G. chiragra.*

There are no lateral spines on the telson. The intermediate spines are about half as long as the submedians. The inner margins of the latter bear a row of from nine to twelve slender spinules. There is in most of the specimens a single similar spinule on the outer margin of the submedian spines and one on the inner margin of the intermediates. In one specimen I found traces of more spinules on the outer margin of the submedians, on one side of the specimen only.

The inner spine of the ventral prolongation of the uropods is longer than figured by Paulson, being at least half the length of the outer. The latter has the very distinct shape shown in Paulson's figure, with the distal extremity rather strongly incurved.

The uropods (Pl. **27.** fig. 6) are very distinctive. The peduncular segment bears a strong spine dorsally on the distal margin. The basal segment of the exopod projects far beyond the articulation of the ultimate segment, and bears on its outer margin, at the distal end, three (in one case two) stout strongly falciform spines, outwardly recurved, and proximally to these, from three to five short straight spines. On the dorsal surface of the basal segment of the uropods, near to the articulation of the distal segment, there is a pad of rather long densely plumose setæ. The dorsal surface of the distal segment of the exopod is beset all over with short plumose setæ and the margins all round with longer plumose setæ. The ventral surface is smooth.

The dorsal surface of the endopod is smooth but the ventral surface is clothed with short plumose setæ, with a bunch of longer setæ on the proximal part, while the margins are armed all round.

The present specimens show the closest resemblance to Paulson's figures, and the main differences are in minor points which may quite reasonably have been overlooked by Paulson in his specimens. These differences are (1) the presence of spinules on the margins of the teeth of the telson, (2) the presence of a faint carina lateral to the submedian carinæ of the telson, (3) the presence of two tubercles near the anterior margin of the telson, one on each side of the median elevation, and (4) the special and peculiar armature of setæ on the uropods.

With the exception of the last character, which is likewise not noted by Lenz, these differences bring *G. brevisquamatus* into closer agreement with *G. fimbriatus*, Lenz. The most serious differences between my specimens and *G. fimbriatus* are:—

(1) The form and size of the carinæ of the sixth abdominal segment. Lenz figures the submedians and intermediates as more or less equal in size, whereas in my specimens the submedians are distinctly wider than the intermediates.

(2) The presence of *two* carinæ on each side of the submedian carinæ of the telson.

Minor differences may also be noted in the different shape of the outer spine of the ventral prolongation of the uropod, in the larger size of the intermediate teeth of the telson, and in the absence of the short straight spines proximal to the strong recurved spines on the outer margin of the exopod of the uropods.

I do not think that any great weight is to be attached to these differences. Some are no doubt due to age or to individual variation. Borradaile, it is true, identifies specimens from the Seychelles with *G. fimbriatus* without comment, but the examination of these specimens from the Red Sea, undoubtedly *G. brevisquamatus*, Paulson, has served to lessen the gap between this species and *G. fimbriatus*, and I feel no doubt as to the correctness of Mr. Patience's conclusion that they are synonymous.

G. brevisquamatus has been recorded from the Red Sea by Paulson and Nobili, and as *G. fimbriatus* from Zanzibar (Lenz) and the Seychelles (Borradaile).

GONODACTYLUS PULCHELLUS, *Miers*, 1880. *See* Kemp, 1913, p. 177, pl. 10. figs. 117, 118.

Locality. Station VIII. B, 1 ♂, 39 mm.

Remarks. I have adopted Kemp's opinion in considering this form worthy to rank as a species distinct from *G. spinosus*. Even after ten years preservation in spirit the dark spots on the sixth, seventh, and eighth thoracic segments, and on the first, fourth, and fifth abdominal segments are distinctly visible, very distinct on the sixth thoracic and first abdominal segments, paler on the seventh thoracic segment, and very faint on the other segments.

Distribution. Not actually recorded from the Red Sea previously though noted from Aden by Nobili; for other records, see Kemp, 1913.

DECAPODA.

Suborder NATANTIA.

Tribe **PENÆIDES.**

Family PENÆIDÆ.

Subfamily PENÆINÆ, *Alcock.*

Genus PENÆOPSIS, *A. Milne-Edwards.*

PENÆOPSIS STEBBINGI (*Nobili*, 1904). (Pl. **27**. figs 7–10; Pl. **28**. fig. 13.)

Metapenæus stebbingi, Nobili, 1904, p. 229.
,, ,, ,, 1906 *a*, p. 15, pl. 1. fig. 2.
,, ,, Alcock, 1906, p. 50.
,, ,, De Man, 1911 *a*, pp. 9 & 54.

Localities. Station I. E, 14 ♀ and 15 ♂, 70–90 mm. Station VIII. A, 2 ♂, 50 mm. and 55 mm. Station X., 1 ♀, 60 mm. Station I. B, 1 juv., 27 mm. From Ray's stomach, several juv.

Remarks. Nobili makes no mention of the fact that this species is without exopodites on the last pair of thoracic legs. It, therefore, clearly belongs to the *monoceros* group of species characterized by the absence of exopodites on the last pair of thoracic legs, and by the fact that the merus of the last pair of thoracic legs in the male is notched at its proximal end. It differs from most of the members of this group by having 6–8 small movable spinules on the telson.

I have very little to add to Nobili's description, but his figures are perhaps a little too diagrammatic. I have refigured the carapace, thelycum, and petasma, and added a figure of the notch on the merus of the last thoracic legs of the male. There is a distinct trace of an extra-orbital spine, and the lower anterior corner of the carapace is rounded and not acute as in Nobili's figure.

P. stebbingi is a very distinctive species as far as the thelycum and petasma are concerned, and adult specimens are readily recognizable on these characters.

The last two records given above must be considered as doubtful. The young male, 27 mm. long, from Suez, differs from adult specimens in having a shorter rostrum, which only reaches to the level of the anterior end of the eyes, and in the want of a notch on the merus of the last thoracic legs. The latter are without exopod. The petasma is symmetrical, but the two portions are still free from one another. In its other characters it seems to agree with *P. stebbingi*. The specimens from the stomach of a Ray are all young and not in good preservation, but appear to belong to this species as nearly as it is possible to decide.

P. stebbingi has not been met with outside the Red Sea, from which Nobili records specimens taken at Suez. It would appear to be an abundant species in the neighbourhood of the latter town.

PENÆOPSIS STRIDULANS (*Wood-Mason*).

See Alcock, 1906, p. 27, pl. 5. figs. 14, 14*a–d*; and De Man, 1911 *a*, p. 65, pl. 7. figs. 20 *a–b*.

Locality. Station VIII. A, 2 ♀, 50 and 55 mm.

Remarks. According to De Man, *P. stridulans* shows a considerable amount of variation in the form of the thelycum, the carinæ on the third abdominal segment, and in the form of the stridulating organ, among other characters. These two specimens agree with the account given by Alcock and would appear to be typical specimens of the species.

Not previously recorded from the Red Sea, though it is quite possible that Paulson's record of *P. velutinus* may refer to this species or the next.

PENÆOPSIS VAILLANTI (*Nobili*). (Pl. 27. fig. 12.)

Metapenæus vaillanti, Nobili, 1904, p. 229.
„ „ „ 1906 *a*, p. 18, pl. 1. fig. 4.
„ „ Alcock, 1906, p. 50.
„ „ De Man, 1911 *a*, pp. 9 and 54.

Locality. Station VIII. A, 1 ♂, 52 mm., and 2 ♀, 49 and 55 mm.

Remarks. This species belongs to the *velutinus* group, characterized by the tomentum of the body, the possession of exopods on all the thoracic legs, the absence of a notch on the last pair of legs in the male, the presence of long stout movable spines on the telson, and the asymmetrical form of the petasma.

As in most species it is mainly distinguished by the form of the thelycum and petasma and, as Nobili's figure of the former is somewhat too diagrammatic, I reproduce one here (Pl. 27. fig. 12).

Recorded from Suez and other places in the Red Sea by Nobili, but not known as yet from waters outside that area.

Genus TRACHYPENÆUS, *Alcock.*

TRACHYPENÆUS ANCHORALIS (*Spence Bate*, 1888, p. 258, pl. 35. fig. 1).

T. anchoralis, De Man, 1911 *a*, p. 88, pl. 8. fig. 28.
Metapenæus curvirostris, Nobili, 1906 *a*, p. 20.

Locality. Station VIII. A, 1 ♂, 48 mm., and 1 ♀, 67 mm.

Remarks. Trachypenæus curvirostris of Stimpson is the type species of the genus, and *T. anchoralis* (Spence Bate) was regarded by Alcock as a synonym. The researches of Kishinouye and De Man have demonstrated that the two forms are distinct and may be recognized by the form of the petasma and thelycum. My specimens are in substantial agreement with the descriptions and figures of Spence Bate and De Man, of specimens which both authors attribute to *T. anchoralis.*

I think there can be little doubt that the specimens recorded as *Metapenæus curvirostris* by Nobili are to be referred to *T. anchoralis.*

Previously recorded from the Red Sea at Massaouah by Nobili, 1906.

Genus PENÆUS, *Fabricius.*

PENÆUS SEMISULCATUS, *De Haan*, 1849, p. 191, pl. 46. fig. 1.

See De Man, 1911 *a*, p. 97, pl. 9. figs. 31 *a–b*.

Locality. Station V. F, 1 ♀, 160 mm.

Remarks. This specimen agrees exactly with De Man's redefinition of this species, and I am in agreement with his suggestion that the *P. monodon* of Alcock is synonymous with this form. Nobili has recorded this species from the Red Sea under the name *P. ashiaka*, Kishinouye, which De Man regards as synonymous with *P. semisulcatus*, De Haan. Other records from the Red Sea include those of Paulson (1875) and De Man (1880). Colosi (1918), however, says that Paulson's records refer to *P. carinatus*, Dana.

PENÆUS JAPONICUS, *Spence Bate*, 1888, p. 245, pl. 31, pl. 32. fig. 4, and pl. 37. fig. 2.

See De Man, 1911 *a*, p. 107.

Localities. Station I. E, 6 ♀, 160–185 mm. Station VIII. A, 2 ♂, 62 and 72 mm., 1 ♀, 66 mm.

Previously recorded from the Red Sea by Nobili.

Subfamily SICYONINÆ, *Ortmann.*

Genus EUSICYONIA, *Stebbing*, 1914 *b*.

EUSICYONIA CARINATA (*Olivier*, 1811, p. 667).

Sicyonia sculpta, H. Milne-Edwards, 1830, p. 339, pl. 9. figs. 1-8.
„ „ Spence Bate, 1888, p. 294, pl. 43. fig. 1.

Locality. Station II., 1 ♀, 46 mm.
Not previously recorded from the Red Sea.

Tribe CARIDES.

Super-family **Palæmonoida.**

Family ALPHEIDÆ.

Genus ATHANAS, *Leach.*

ATHANAS DJIBOUTENSIS, *Coutière*, 1897 *b*, p. 233. (Pl. **28.** fig. 25.)

A. djiboutensis, Coutière, 1905, p. 856, fig. 129.

Localities. Station V. C, 1 ovig. ♀, 8 mm., 3 ♂, 8–9 mm. Station VII. D, 1 ovig. ♀, 8 mm. Station VII. B, 1 ovig. ♀, 7 mm., 2 ♂, 5–7 mm, Station IX. A, 1 ♂, 7 mm.

Remarks. Of the nine specimens which I refer to this species, three are egg-bearing females and six are males. They were collected between the end of January and the end of April, which presumably covers the breeding season of the species in the Red Sea. With the exception of the form of the first pair of legs, there is very little to add to Coutière's description. The rostrum shows some variation in length, but in all the specimens it is longer than the first two segments of the antennular peduncle and never exceeds the whole length of the latter. The supra-, extra- and infra-ocular spines agree very closely in form and relative proportions with Coutière's figures, and the stylocerite in all the specimens reaches as far forward as the distal end of the second joint of the antennular peduncle. One of the female specimens still retains one of the first pair of legs (the left), and this appendage is in close agreement with Coutière's figure 129*f*. Among the male specimens, imperfect as they are, I have noted some interesting points in the form of the first pair of legs. I should explain that I have relied for the determination of the sex of the specimens on the presence of an appendix masculina on the second pleopods, which is well developed on all the male specimens. The form of the first pair of legs in these specimens, as far as they are present, may be noted as follows :—

(1) Two specimens have both the first pair of legs missing.

(2) One specimen, 8 mm., lacks the left leg of the first pair. The right one is a regenerated limb, very like the smaller chela of the female as figured by Coutière (fig. 129*f*), but with the carpus relatively much shorter.

(3) One specimen, 5 mm., lacks the right leg of the first pair. The left one is exactly of the same form as the smaller chela of the female, and is in this specimen not a regenerated limb.

(4) One specimen, 9 mm., has both legs of the first pair present and they agree in all particulars with Coutière's descriptions and figures (fig. 129*c* and *d*).

(5) One specimen, 9 mm., lacks the left leg of the first pair. The right one is of the same form, size, and proportions as shown by Coutière for the larger chela of the male (fig. 129*c*), but the immovable finger bears a broad high tubercle in the centre of its inner margin, and the movable finger has a prominent smaller tubercle on its inner margin proximal to the tubercle on the fixed finger (Pl. **28**. fig. 25).

Kemp (1915, pp. 289–299) has recently described and discussed at length a most remarkable and interesting case of "trimorphism" among the males of a new species of *Athanas*, *A. polymorphus*, Kemp, discovered by him in the Chilka Lake, India. He found three forms of males as follows :—

Form I. Small in size. First pair of legs asymmetric, one enlarged, without tooth on fixed finger, the other slender and of the size and proportions of those of the female.

Form II. Large in size. First pair of legs symmetrical, no tooth on fixed finger.

Form III. Of same size as Form II. First pair of legs asymmetric. One of them with a prominent rounded tooth on the fixed finger, the other without such tooth.

In all three forms the appendix masculina on the second pleopods was well developed, but form I. was met with in the non-breeding season only, and forms II. and III. in the breeding-season only.

After discussing the phenomenon in all its aspects, Kemp inclines to the opinion that forms II. and III. are true dimorphic forms developed simultaneously at the breeding-season from the non-breeding form I.

Regarded in the light of Kemp's observations the males of *A. djiboutensis* noted above appear to show a close parallel to the case of *A. polymorphus.* The small male (No. 3) probably corresponds to Kemp's form I., and the males 4 and 5 to forms II. and III. The want of the full complement of limbs precludes an absolute comparison.

But the small male, form I., was taken in the company of an ovigerous female and therefore in the breeding-season. It is possible that the capture was made at the very beginning of the breeding-season before this male had moulted into its full adult stage. But another explanation of the facts suggests itself. Kemp notes that in all the forms the appendix masculina on the second pleopods was well developed, and the same observation applies in the present case. I suggest therefore that form I. is a breeding phase and that *Athanas* becomes sexually mature before it is fully grown. This would explain the full development of the appendix masculina and receive support from the capture of a form I. male in the breeding-season. We may turn to the Amphipoda for the necessary analogy.

Walker, in a paper "Notes on *Jassa falcata* (Mont.)" (Proc. Trans. L'pool. Biol. Soc., vol. xxv. pp. 67–72, 1911) calls attention to an interesting series of facts. In a single gathering of Crustacea made from a buoy moored in the harbour of Port Erin, he found an enormous number of specimens of the Amphipod *Jassa falcata* which could be divided up into groups. The circumstances of their capture and the area of their occurrence afford the strongest evidence that all the specimens belong to one species. Walker found two groups of ova-bearing, *i. e.* sexually mature, females differing not only in size but in the form of the gnathopods. In other words, here is evidence that Crustacea may be sexually mature though not structurally fully grown. A similar phenomenon is not so easily demonstrable for males except by sections, but, given its occurrence in females, there seems to me to be no inherent difficulty in accepting its occurrence in males. Walker also found three forms of males which he interprets as a penultimate form and two forms of the fully-grown male, into one or other of which the penultimate form moults.

We have in this case, I think, an interesting parallel to what Kemp has observed in *Athanas polymorphus*, and to what probably occurs in *Athanas djiboutensis* so far as the imperfect specimens at my disposal can be interpreted.

Walker's evidence, coupled with the occurrence of a form I. male of *A. djiboutensis* in the breeding-season and the well-developed appendix masculina present on all three forms of male, has led me to suggest that Kemp's observations may be explained on the following grounds:—that all three forms of male are breeding forms, that form I. is sexually mature but not structurally fully grown and eventually moults into either form II. or III., which are truly dimorphic forms of the fully-grown male. From the nature of the material at my disposal this can be no more than a mere suggestion. The specimens are too few and too fragmentary for a definite statement, but perhaps Mr. Kemp himself at some future time may be able to clear the matter up by personal observation on living material.

Distribution. Djibouti and Minikoi (Coutière) and Funafuti (Borradaile). Also recorded from an unnamed locality in the Red Sea by Nobili.

ATHANAS DIMORPHUS, *Ortmann*, 1894, p. 12, Taf. I. fig. 1. (Pl. **28**. figs. 23–24.)

Locality. Station I. B, 1 ♂, 15 mm., and 1 ♀, 14 mm.

Remarks. The female has lost both legs of the first pair so that it is not possible to be quite sure of its identity. It agrees, however, very closely with the male caught with it, and I have no doubt belongs to the same species. This male specimen I identify with *Athanas dimorphus*, Ortmann, in spite of some differences, mainly in the form of the first pair of legs. These appendages are both fortunately present in the specimen. They are not equal in size, the right being slightly the larger of the two, and the degree of difference between the right and left being of much the same extent as exists in *A. djiboutensis*. The movable finger of the right leg bears a prominent tubercle on its inner margin near the base, while the fixed finger has a larger and broader tubercle on its inside margin (Pl. **28**. fig. 23). The condition of the right chela in this specimen is, in fact, very much as I have noted in *A. djiboutensis*. The smaller left chela is shown in Pl. **28**. fig. 24. The fixed finger here bears a smaller and more obscure tubercle in the same position as the prominent one on the right chela. This male specimen therefore corresponds to Kemp's male form III., and as such is evidence that *A. dimorphus* likewise has truly dimorphic forms of the fully-grown male, corresponding with what I have described in *A. djiboutensis* above. It is somewhat extraordinary that Coutière, who has apparently seen numerous specimens of this species from various localities in the Red Sea, did not come across this second form of the male, for I can find no reference to the tubercles on the inner margin of the chela in any of his descriptions.

Distribution. Red Sea at Suez, Perim, and Djibouti (Coutière). Dar-es-Salaam, E. Africa (Ortmann).

There are two further specimens of *Athanas* in the collection which may be provisionally referred to this species with considerable doubt. Both are females, taken on the Suez Mud Flats, and neither of them possesses any of the walking-legs. They differ from *A. dimorphus* in the form of the extra- and infra-corneal spines of the carapace.

The extra-corneal spine is shorter than the infra-corneal spines and does not reach more than half-way across the corneal face of the eye. Both spines are moreover broader and less acute than the same spines in *A. dimorphus*.

Beyond this difference there is no other substantial disagreement with the characters of the latter species which can be noted in the absence of the walking-legs.

ATHANAS PARVUS, *De Man*, 1910, p. 515.

See De Man, 1911 *b*, p. 148, pl. 1. fig. 4.

Locality. Station V. B, 2 ♀, 7 mm., carrying eggs.

Locality uncertain. 1 ♂, 8 mm., labelled as part of the fauna of two dead valves of *M. margaritifera* which were covered by sponges and supported a regular microcosmos of life; 1 ovig. ♀, 7 mm., labelled Crust. fr. 44.

Remarks. It is with some reserve that I refer these specimens to De Man's species. They agree, as far as they go, with his description, except that the rostrum somewhat exceeds and the stylocerite does not quite extend to the distal margin of the second joint of the antennular peduncle. In the form of the extra- and infra-corneal spines, the proportions of the first pair of legs in the female, and the bi-unguiculate character of the dactylus of the three posterior pairs of legs, they agree well with De Man's observations. The male specimen unfortunately is devoid of all the walking-legs.

Distribution. S. coast of Timor (De Man).

New to the fauna of the Red Sea.

ATHANAS CROSSLANDI, n. sp. (Pl. **27**. figs. 13–17.)

Locality. Station V. C, 2 ovig. ♀, 6 and 7 mm.

Description. The rostrum reaches forward to the middle of the third joint of the antennular peduncle. There is no supra-orbital spine. The extra-corneal spine (Pl. **27**. fig. 13) is remarkable for its great length, being almost half as long as the rostrum and extending for half its length beyond the eye. The infra-corneal spine is quite short. The antennular peduncle (Pl. **27**. fig. 14) is somewhat short and robust with the last two joints subequal in length. The stylocerite reaches to the middle of the second joint. The antennal scale (Pl. **27**. fig. 15) is equal in length to the antennular peduncle and is twice as long as broad, with the terminal spine of the outer margin well developed but not projecting beyond the scale itself. The carpocerite reaches the distal end of the second joint of the antennular peduncle.

Legs of the first pair in the female (Pl. **27**. fig. 16) equal and feeble, and of the form characteristic of the *nitescens* group. The merus is one and a half times as long as the carpus and one quarter shorter than the whole chela. The proportions of the limb are, taking the fingers as 1 : merus 2, carpus 1·3, palm 1·6, fingers 1.

The second pair of limbs are long and slender. The proportions of the joints of the carpus are 4 : 1·45 : 1·27 : 1 : 1·72. The whole chela is about as long as the first joint of the carpus, and the fingers are about equal in length to the palm.

The third pair of legs (Pl. 27. fig. 17) are slender, with the joints in the following proportions, taking the finger as 1: merus 2, carpus 1·5, propodus 2·5, finger 1.

The dactylus is simple, and there are spines on the inner distal margin of the propodus.

Among described species of the genus, *A. crosslandi* agrees with *A. dimorphus*, *A. minikoensis*, *A. haswelli*, *A. orientalis*, and *A. polymorphus*, to the exclusion of all the other species, by the combination of the two characters, the absence of a supra-orbital spine on the carapace and the simple character of the fingers of the last three pairs of legs. But the five species mentioned all belong to the *dimorphus* group, and though there are no male specimens of *A. crosslandi* available, the form of the first pair of legs of the female point to its affinities with the *nitescens* group, in which its nearest relative is *A. naifaroensis*, Cout. It is, however, distinguished from the latter species by the absence of a supra-orbital spine, and the great length of the extra-corneal spine will serve to distinguish it from most of the species of this group.

Genus SYNALPHEUS, *Sp. Bate*, 1888.

Neomeris group.

SYNALPHEUS GRAVIERI, *Coutière*, 1905, p. 870, pl. 70. fig. 2.

S. gravieri, De Man, 1911 *b*, p. 216, pl. 6. fig. 25.

Locality. Station III., 2 ♀, 10 and 12 mm.

Remarks. The smaller of these specimens has only one spine and the larger two spines, on the merus of the third pair of legs. Otherwise the specimens are in close agreement with Coutière's description.

Distribution. The only previous record for the Red Sea is that of Coutière (1905) from Djibouti. Otherwise known from the Maldives (Coutière, 1905), Ceylon (Pearson, 1905 & 1911), Dutch East Indies (De Man, 1911), Chinese and Japanese waters (Ortmann & Coutière).

SYNALPHEUS STREPTODACTYLUS, *Coutière*, 1905, p. 870, pl. 70. fig. 1.

S. streptodactylus, De Man, 1911 *b*, p. 226, pl. 7. fig. 29.

Localities. Station IV., 1 ♂, 11 mm., 1 ♀ with eggs, 14 mm.

Uncertain. 1 ♂, 10 mm., 1 ovig. ♀, 14 mm., labelled Crust. fr. 44.

Distribution. Not previously recorded from the Red Sea. Otherwise known from the Maldives (Coutière, 1905), Ceylon (Pearson, 1911), Dutch East Indies (De Man, 1910), Atjeh and Ternate (De Man).

SYNALPHEUS TRIUNGUICULATUS (*Paulson*), 1875, p. 103, pl. 14, figs. 1–1 *g*.

S. triunguiculatus, Nobili, 1906 *a*, p. 31.
S. triungicuulatus, Nobili, 1906 *b*, p. 25.

Localities. Station V. C, 2 ♀, one with eggs, 10 and 12 mm. Station V. D, one juv., 6 mm. Station VII. C, 1 ♂, 14 mm., 1 ♀, with eggs, 15 mm.

Remarks. These specimens agree very closely with Paulson's figures and seem clearly referable to his species.

Distribution. This species has been recorded from various localities in the Red Sea by Paulson, Coutière, and Nobili. So far as I am aware it has not been taken in any other area of the Indo-Pacific Ocean, with the exception of the Persian Gulf (Nobili, 1906 *b*).

SYNALPHEUS FOSSOR (*Paulson*), 1875, p. 103, pl. 13. fig. 5.

S. fossor, Coutière, 1905, p. 872, pl. 70. fig. 6.
See also De Man, 1911 *b*, p. 250, pl. 9. fig. 39.

Localities. Station VIII. C, 3 ♀, 7–11 mm. Station XI., fourteen specimens, 4–10 mm. (in green sponge).

Remarks. These specimens seem to combine the characters of the type-form and the var. *propinqua*, De Man. They agree with the former in having the carpocerite six times as long as broad, and with the latter in having nine spinules on the propodus of the third pair of legs, and in the proportions of the merus of these limbs. The strongly spinous corners of the apex of the telson are always well marked, but they may be longer or shorter than the first of the spines on the apex. This character does not seem to vary with age. Otherwise these specimens are in the closest agreement with Paulson's figures.

Distribution. Recorded previously from the Red Sea by Paulson; Maldive Archipelago (Coutière); the var. *propinqua* is known from various parts of the Dutch East Indies and adjacent waters.

SYNALPHEUS HERONI, *Coutière*, 1909, p. 42, fig. 24.

S. heroni, De Man, 1911 *b*, p. 256, pl. 9. fig. 41.

Locality. Station IX. A, 4 ♀ (one ovig,), 7–10 mm.

Distribution. Red Sea at Djibouti (Coutière); Dutch East Indies (De Man).

Paulsoni group.

SYNALPHEUS HULULENSIS, *Coutière*, 1908, p. 12.

S. tumidomanus, Coutière, 1905, p. 876, pl. 63. fig. 14.
S. hululensis, Coutière, 1909, p. 24, fig. 4.

Locality. Station IX. A, 1 ♂, 8 mm., 1 ovig. ♀, 9 mm., 1 juv., 6 mm.

Remarks. Both the carpocerite and the merus of the third legs are four times as long as wide. The telson is not spinous at the lateral corners of the apex. The species seems to me to be very closely allied to *S. tricuspidatus* of Heller.

Distribution. New to the fauna of the Red Sea. Only recorded by Coutière from the Maldives.

Biunguiculatus group.

SYNALPHEUS BIUNGUICULATUS (*Stimpson*) *Coutière.*

S. biunguiculatus, Coutière, 1905, p. 873, pl. 71. fig. 8.
S. biunguiculatus, De Man, 1911 *b*, p. 273, pl. 11. fig. 51.

Localities. Station V. B, one broken. Station V. A, one, 10 mm. Station V. C, 1 ♂, 12 mm., and 1 ♀, 15 mm. Station X., 1 ♀, 15 mm.

Remarks. All these specimens belong to the typical form of the species as defined by De Man.

Distribution. Previously recorded from the Red Sea by Coutière, from Suez and Djibouti; Maldives and Laccadives (Coutière); Dutch East Indies (De Man).

Nobili has recorded this species from Massaouah in the Red Sea, but De Man states that it is not possible to say what species he had under observation.

SYNALPHEUS SAVIGNYI (*Guérin*), 1856, pp. 47–51, pl. 2. figs. 8–11.

Athanas nitescens, Audouin & Savigny, 1826, p. 90, pl. 9. fig. 4. See also Coutière, 1899, p. 17.

Locality. Station I. F, 1 ♀, 15 mm.

Remarks. I have not been able to consult Guérin's works, and I am indebted for the reference thereto to Coutière. The single specimen at my disposal agrees absolutely with Savigny's figure, and I have little doubt that it belongs to the species which Savigny had under observation and, moreover, it seems to me that Savigny's figure is an extraordinarily faithful reproduction of the species. *S. savignyi* is very nearly allied to *S. biunguiculatus*, and before I was able to consult Savigny's work I had noted it as a variety. The rostrum is exactly as figured by Coutière for *S. biunguiculatus* except that the left tooth of the trident is almost obsolete. The carpocerite is slightly longer than the antennular peduncle, while the scaphocerite is equal in length to the latter. The antennal scale reaches forward to the distal end of the second joint of the antennular peduncle. The inferior spine of the basicerite is equal to the stylocerite, while the superior spine of the basicerite is quite well developed.

The outstanding feature of the species is to be found in the palm of the large chela (the left one in this case), which ends anteriorly in a sharp spine directed straight forward. In *S. biunguiculatus* the palm ends anteriorly in a bluntly rounded tubercle. The dactylus of the smaller chela is without a dorsal brush of hairs. The merus of the third legs is four times as long as wide, with three or four movable spinules on the distal third of its lower margin. In this character it resembles *S. pachymeris*, Cout. The carpus of these limbs has a single spine on the distal corner of the lower margin and the propodus bears seven or eight spinules.

The species differs from *S. biunguiculatus* in the form of the large chela and in having spinules on the merus of the third legs. In the latter character it agrees with *S. pachymeris*, but differs from this species in the rostrum and large chela.

The specimen was infected by an abdominal Bopyrid.

Distribution. *S. savignyi* does not appear to have been seen since it was originally described and figured by Audouin and Savigny. Its rediscovery is therefore a matter of considerable interest. Savigny's specimen probably came from the Red Sea though no precise locality is given.

SYNALPHEUS QUINQUEDENS, n. sp. (Pl. **28**. figs. 1–5.)

Localities. Station I. D, 1 ♀, 18 mm. Station V. E, 1 ♀ with eggs, 20 mm. Station VI., 1 ♀, 16 mm. Station VII. F, 1 ♀, 19 mm.

Uncertain. 1 ♂, 13 mm., 1 ♀, ovig., 13 mm., labelled "part of the fauna of two dead valves of *M. margaritifera* which were covered by sponges and supported a regular microcosmos of life."

Description. A new species of the *biunguiculatus* group, belonging to that section of the group characterized by having the posterior margin of the sixth abdominal somite armed with teeth. In *S. quinquedens*, the posterior margin of the sixth abdominal somite is armed with a prominent obtuse spine or tooth at each lateral corner and between them, three other smaller blunt teeth more or less equidistantly placed (Pl. **28**. fig. 5).

The general form of the body is robust and tumid, and there are a few very scattered quite short hairs on the carapace and abdomen.

The three prongs or spines of the rostral plate (Pl. **28**. fig. 1) are equal in length and extend forward about half-way along the basal joint of the antennular peduncle. The central spine is narrower than the laterals, of more or less equal width throughout. The lateral spines are broad and obtuse. Each of the rostral spines is tipped by a few short setæ.

The antennular peduncle (Pl. **28**. fig. 1) has the third joint shorter than the second and the stylocerite slightly longer than the basal joint.

The carpocerite (Pl. **28**. fig. 1) is five times as long as wide, and projects beyond the antennular peduncle by about one-sixth of its length. The terminal spine of the scaphocerite is equal to or slightly shorter than the antennular peduncle, while the antennal scale reaches to the level of the distal end of the second joint of the antennular peduncle. The lateral spine of the basicerite is very acute and as long as the first joint of the antennular peduncle, therefore slightly shorter than the stylocerite. The spine at the upper angle of the basicerite is well developed, acute, about one-third as long as the lateral spine.

The telson (Pl. **28**. fig. 5) is two and a third times as long as wide at the posterior margin. Its posterior angles are acute but not spinous, and immediately inside of them the posterior margin bears two spines on each side, the inner of which is slightly the longer. The usual two pairs of dorsal spines are present, rather robust in form, the posterior pair situated about the middle of the telson.

The larger cheliped (Pl. **28**. fig. 2) is of the general form found in *S. biunguiculatus*. The merus is triangular in cross-section, each angle of the triangle marking a carina running longitudinally down the joint and ending distally in acute spines. The carpus is acutely spinous at its lower distal corner. The chela is rather more than 2½ times as long as broad, quite smooth and oval in form. The anterior margin of the palm ends in an acute but not spinous tubercle. The fingers are about one quarter of the length of the whole chela.

The merus of the smaller cheliped is three times as long as wide, unarmed at the apex, with numerous long setæ on the inner margin. The whole chela is three times as long as broad, the palm being two-thirds of the total length and the fingers one-third. The movable finger is tapering and furnished with stiff setæ at its tip.

The merus of the second pair of legs (Pl. **28**. fig. 3) is very nearly five times as long as wide. The carpus is about equal in length to the merus, the first joint equal in length to the succeeding four, the last joint longer than the combined length of the third and fourth. The chela is very slightly shorter than the first joint of the carpus, with the fingers one and a half times as long as the palm and fringed with long tufts of setæ.

The third pair of legs (Pl. **28**. fig. 4) are of relatively stout form. The merus is rather more than three times as long as broad and unarmed. The carpus is four-ninths and the propodus two-thirds as long as the merus, the carpus being unarmed and the propodus bearing seven short spines on its inner margin. The dactylus is very short with the secondary nail well developed. Length of the only male 13 mm., of the female 13–20 mm., the smallest as well as the largest of which are ovigerous.

This species falls within that group of forms belonging to the *biunguiculatus* division of the genus, in which the posterior margin of the sixth abdominal somite is armed with teeth. De Man has described six species in the Siboga Report, belonging to this group: *S bispinosus*, *S. triacanthus*, *S. quadridens*, *S. quadrispinosus*, *S. trispinosus*, and *S. septemspinosus*, the specific names of which refer to the number of teeth on the posterier margin of the sixth abdominal somite. Following this nomenclature, the specific name of the new species here described indicates at once the main point of difference from the species described by De Man. Among De Man's species, *S. quinquedens* is at once distinguished from *S. triacanthus*, *S. trispinosus*, and *S. septemspinosus* by the character of the rostral plate. In the first two species the central spine is exceedingly long, much longer than the lateral teeth and as long as or longer than the first joint of the antennular peduncle. In *S. septemspinosus* the central prong of the rostral trident is longer than the laterals, whereas in *S. quinquedens* all three are equal. *S. trispinosus* and *S. septemspinosus* are further distinguished from *S. quinquedens* by having the merus of the third legs armed with seven or eight spinules. Of the other three species, *S. quinquedens* approaches most closely to *S. quadrispinosus*, differing only in the extra spine on the sixth abdominal segment.

This group of species is most nearly related to the type-form of the division of the genus to which they belong, *S. biunguiculatus*, and in fact, but for the armature of the sixth abdominal somite, would be difficult to separate from that species.

Genus ALPHEUS, *Fabricius*.

Macrochirus group.

ALPHEUS GRACILIS, *Heller*, 1861, p. 271, Taf. 3. figs. 19, 20.

See De Man, 1911 *b*, p. 337, pl. 14. fig. 60.

Localities. Station VII. B, 1 ♂, 16 mm., 1 ♀ with eggs, 17 mm. Station IX. A, 4 ♂, 9–17 mm., 4 ♀, 9–16 mm., three of which, 12–16 mm. in length, were carrying eggs.

Distribution. The type-form has so far not been met with outside the Red Sea, from which both Heller and Coutière have recorded the species. The var. *alluaudi*, Coutière, is known from Mahé and the var. *luciparensis*, De Man, from Lucipara Island in the Dutch East Indies.

ALPHEUS VENTROSUS *, *H. M.-Ed.*, 1837, p. 352.

A. ventrosus, Coutière, 1905, p. 882.
A. ventrosus. De Man, 1911 *b*, p. 339.

Localities. Station VII. B, six specimens. Station V. E, several.

Distribution. Recorded previously from the Red Sea by Heller, Paulson, Kossmann, De Man, Miers, Nobili, and Coutière; widely distributed throughout the Indian and Pacific Oceans.

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* Stebbing (1915) identifies this species with the earlier described *Alpheus lottini*, Guérin, which name it should accordingly bear.

Crinitus-obeso-manus group.

ALPHEUS MICROSTYLUS, *Sp. Bate*, 1888, p. 566, pl. 101. fig. 6.

A. microstylus, Coutière, 1905, p. 884, pl. 76. fig. 23.
A. microstylus, De Man, 1911 *b*, p. 344.

Locality. Section V. E, 2 ♂, 20 and 22 mm.

Distribution. Previously recorded from the Red Sea by Coutière from Djibouti and Mascat; widely distributed in the Pacific Ocean.

Crinitus-crinitus group.

ALPHEUS ALCYONE, *De Man*, 1902, p. 870, Taf. 27. fig. 61.

A. alcyone, Nobili, 1906 *b*, p. 32.
A. aculeipes. Coutière, 1905, p. 892, pl. 79. fig. 31.
A. alcyone, De Man, 1911 *b*, p. 351.

Locality. Station V. C, one specimen, 10 mm.

Distribution. Previously recorded from the Red Sea by Coutière from Djibouti; widely distributed in the Indian Ocean.

ALPHEUS sp.?

Locality. Station V. A, 1 ♂, 10 mm.

Remarks. This specimen approaches *A. alcyone* very closely, but differs from it mainly in the fact that the median rostral process is absent or obsolete so that the rostrum presents the form of an emarginate plate.

The dactylus of the last three pairs of legs has a very small accessory tooth so that it is obscurely bi-unguiculate. There is no prominent spine on the distal corner of the lower margin of the carpus of the third legs, but there are two spines on the median portion of this margin. The second joint of the carpus of the second pair of legs is about three times as long as the first. The other characters are exactly as in *A. alcyone*.

ALPHEUS BUCEPHALOIDES, *Nobili*, 1905 *b*, p. 238.

A. bucephaloides, Nobili, 1906 *b*, p. 29.

Localities. Station V. E, 1 ♂, 9 mm. Station IX. A, 1 ♂, 10 mm.

Remarks. It is with a considerable amount of reserve that I refer these specimens to Nobili's species. They differ from the latter in not having the movable finger of the small cheliped broadened and fringed with setæ, and in having the second joint of the carpus of the second legs 1 3 times as long as the first, instead of 1·6 as in *A. bucephaloides*.

The carpus of the third legs has only three spinules on the lower border in addition to the terminal one and has no spines on the upper border. There is only one spine on the outer uropod at the suture. These small differences may be due to immaturity, as the specimens are in otherwise close agreement with *A. bucephaloides.*

Distribution. This species is new to the fauna of the Red Sea and is otherwise only known from Nobili's record from the Persian Gulf.

ALPHEUS CONSOBRINUS, *De Man*, 1908, p. 101.

A. consobrinus, De Man, 1911 *b*, p. 360, pl. 16. fig. 75.

Localities. Station V. A, 1 ♂, 1 ♀, 14 mm. Station V. D, 1 ♂, 9 mm. Station V. E, 2 ♀, 14 mm. Station VII. C, 1 ♂, 1 ♀, 10 mm. Station IX. A, 1 ♂, 2 ♀, 9 mm.

Remarks. This species is very closely allied to *A. bucephalus,* Coutière, but differs in having the fingers of the small chela of the male expanded and hairy. The differences between the two species do not seem to me to be clearly established, but by reason of the above character I refer my specimens to De Man's species.

Distribution. New to the fauna of the Red Sea; otherwise only known from the waters round the Dutch East Indies.

ALPHEUS PACHYCHIRUS, *Stimpson*, 1860, p. 30.

A. pachychirus, De Man, 1911 *b*, p. 366, pl. 16. fig. 77.

Locality. Station IX. A, 1 ♂, 15 mm.

Distribution. Recorded once previously from the Red Sea by Coutière from Djibouti; widely distributed throughout the Indian and Pacific Oceans.

Crinitus-insignis group.

ALPHEUS INSIGNIS, *Heller*, 1861, p. 269, Taf. 3. figs. 17–18.

A. insignis, Coutière, 1905, p. 899.

Locality. Station IX. A, 1 ♀.

Remarks. This specimen agrees very well with the descriptions of *A. insignis* except that the lateral lobes of the rostrum are not setiferous.

Distribution. Recorded previously from the Red Sea by Heller, Paulson, De Man, Nobili, and Coutière; otherwise widely distributed in the Indo-Pacific Ocean.

ALPHEUS PARACRINITUS, *Miers*, 1881, p. 365, pl. 16. fig. 6.

Locality. Station VII. C, four specimens, 11–12 mm.

Distribution. Recorded by Coutière from the Red Sea at Djibouti; otherwise known from the original record of Miers from Goree Island, Senegambia. A variety of this species, *bengalensis*, Coutière, is known from Minikoi.

Edwardsi group.

ALPHEUS AUDOUINII, *Coutière*, 1905, p. 911, pl. 87. fig. 52.

A. audouinii, De Man, 1911 *b*, p. 414, pl. 23. fig. 100.

Locality. Station V. E, 1 ♂, 21 mm., 1 ♀, 19 mm.

Distribution. This species has hitherto been confused with *A. edwardsii*, Audouin, so that the previous records for the Red Sea are not easy to determine. It has, however, been certainly recorded by Nobili and Coutière from this area.

ALPHEUS STRENUUS, *Dana*, 1852, p. 543, pl. 34. fig. 4.

A. strenuus, Coutière, 1905, p. 913, pl. 87. fig. 53.
A. strenuus, De Man, 1911 *b*, p. 423.

Localities. Station I. A, one specimen, 28 mm. Station V. E, two specimens, 17 and 24 mm. Station VII. C, one specimen, 22 mm.

Distribution. Previously recorded from the Red Sea by De Man, Nobili, and Coutière; a widely distributed Indo-Pacific species.

ALPHEUS BOUVIERI, *A. M.-Ed.*, var. HULULENSIS, *Coutière*, 1905, p. 908, pl. 85. fig. 46.

Locality. Station V. C, 1 ♀, 10 mm.

Distribution. Recorded from the Red Sea by Coutière from Djibouti; otherwise only known from the Maldives.

ALPHEUS PARVIROSTRIS, *Dana*, 1852, p. 551, pl. 35. fig. 3.

A. parvirostris, Coutière, 1905, p. 906.
A. parvirostris, De Man, 1911 *b*, p. 432, pl. 22. fig. 106.

Localities. Station V. A, 2 ♂, 12 and 13 mm., 5 ♀, 9–14 mm. Station V. B, 14 specimens. Station V. C, 2 ♂, 8 and 10 mm. Station V. E, 2 ♂, 13 and 14 mm., 2 ovig. ♀, 12 and 14 mm. Station VII. C, 2 ♂, 12 and 13 mm., 2 ovig. ♀, 12 and 13 mm. Station IX. A, 3 (including 1 ovig. ♀), 5–9 mm.

Distribution. Recorded from the Red Sea by Heller and Coutière; otherwise widely distributed in the Indian and Pacific Oceans.

In addition to the above-named species the collection contained two ovigerous female Alpheids, from among coral in one fathom of water at Mersa Ar-rakiya, which were too much damaged to identify with certainty.

Family HIPPOLYTIDÆ.

Genus SARON, *Thallwitz*.

SARON NEGLECTUS, *De Man*, 1902, p. 854, pl. 26. fig. 58.

S. neglectus, Coutière, 1910, p. 71, figs. pp. 73, 78.
S. neglectus, Kemp, 1914, p. 87.

Locality. Section IX. A, two specimens, 25 mm.
Previously recorded from the Red Sea by Coutière.

Genus THOR, *Kingsley*, 1878.

THOR PASCHALIS (*Heller*, 1861, p. 276, pl. 3. fig. 24).

Paschocaris paschalis, Nobili, 1906 *a*, p. 38, pl. 3. fig. 1.
Thor paschalis, Kemp, 1914, p. 94, pl. 1. figs. 6–10.

Locality. Station V. C, two specimens, 9 mm.

Remarks. The carpus of the second peræpods is six-jointed and the telson bears four pairs of spinules.

Distribution. Previously recorded from the Red Sea by Heller and Nobili. For further distribution see Kemp (*loc. cit.*).

Genus HIPPOLYTE, *Leach*.

HIPPOLYTE PROTEUS, *Paulson* (1875, p. 109). (Pl. **28**. figs. 10–12.)

See Nobili, 1906 *a*, p. 33.

Locality. Exact locality uncertain. The label bears the number W. 12, and I think refers to specimens captured in Suakin Harbour.

Remarks. Two small specimens of *Hippolyte*, 9 and 11 mm. in length, I refer to Paulson's species, with some doubt. Nobili (1906 *a*) has published a translation of Paulson's original description, and to it I am indebted for information on this form. My specimens belong to category A of Paulson and to the first group of that category. The rostrum (Pl. **28**. fig. 10) is equal in length to the antennular peduncle and much shorter than the antennal scale. The upper edge bears three teeth, the first two placed at one-third and two-thirds of the way along the rostrum and the third and smallest tooth near the tip. The larger specimen has two small teeth on the lower edge in the anterior (distal) third, the smaller specimen only one small tooth. The antennal scale (Pl. **28**. fig. 11) is about three and a quarter times as long as broad. The carpus of the second pair of legs (Pl. **28**. fig. 12) has the first joint twice as long and the third joint one and a third times as long as the second. The latter is one and a half times as long as broad.

Nobili regards the category B specimens of Paulson as synonymous with *H. orientalis*, Heller, which Kemp (1914) suggests is possibly a synonym of *H. ventricosus*, M.-Ed. From the latter as redescribed by Kemp, my specimens differ in having a much shorter rostrum. In *H. ventricosus* the rostrum is equal in length to the antennal scale and much longer than the antennular peduncle. In my specimens the rostrum is only as long as the antennular peduncle and much shorter than the scale. There are also differences in the proportions of the joints of the carpus and in the antennal scale, and it seems useful to indicate these by the following table, in which I have incorporated measurements made from Kemp's figures.

	H. ventricosus.	*H. varians.*	*H. proteus.*
Antennal Scale—			
L : B	3·0	3·5	3·25
Joints of Carpus 1	3·0	2·6	2·0
„ „ 2	1·0	1·0	1·0
„ „ 3	1·7	1·4	1·3
2nd joint of Carpus L : B ..	1·0	2·0	1·5

At the same time it is only just to point out that my specimens are not fully grown, and the proportions of the joints of the carpus may change with age. The rostrum is well known to be of very variable form in species of this genus. I record my specimens under the name *H. proteus*, rather with the idea of indicating their structure, than from any conviction that the species is really distinct from *H. orientalis*, Heller, or *H. ventricosus*, M.-Ed.

Family PALÆMONIDÆ.

Subfamily PONTONIINÆ, *Kingsley*, 1878.

Genus PALÆMONELLA, *Dana*, 1852.

PALÆMONELLA TENUIPES, *Dana*, 1852, p. 582, pl. 38. fig. 3.

P. tenuipes, Nobili, 1906 *a*, p. 70.
P. tenuipes, Borradaile, 1917, p. 358.

Localities. Station V. B, one specimen, 10 mm. Station VII. C, three specimens, 10–17 mm

Remarks. I think this is certainly the species recorded by Nobili as *P. tenuipes*, Dana. The main points of difference from Dana's description and figures are:—(1) The relatively longer palm to the chelæ of the second pair of legs; (2) the merus is armed with a spine at the distal extremity of the lower border *only*; (3) Dana makes no mention of the minute teeth on the fingers of the chelæ noted by Nobili and present in these specimens.

The four specimens in the present collection have the rostrum armed with seven or eight teeth above, two of which are on the carapace, and two below. Two of the specimens still retain the second pair of legs, and these, measured, give the following proportions, taking the carpus as unity. These measurements are compared with those given by Nobili in his description of this species and with similar measurements taken from Dana's figure and from Borradaile's figure of *P. tridentata* (1898 *a*, p. 1007, pl. 64. fig. 8). I have added the proportions of the joints of the first legs, derived from the same sources.

	Crossland Red Sea specimens.			Nobili.	Dana.		Borradaile. *P. tridentata.*	
	1st leg.	2nd leg.		2nd leg.	1st leg.	2nd leg.	1st leg.	2nd leg.
Merus	1·0	1·4	1·2	1·1	1·5	1·2	·9	·7
Carpus	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0
Palm	·4	1·7	1·6	1·5	·625	1·2	·5	1·5
Fingers	·35	1·0	1·0	·8	·625	·8	·4	·75

From this table of measurements it will be noted (1) that in Dana's specimens the palm of the second leg is relatively shorter than in either Nobili's specimens or mine, and (2) that my specimens have relatively longer fingers than either Dana's or Nobili's, though Nobili gives the measurements of the palm and fingers of another specimen in which the fingers are relatively longer than in the other limb measured and approach more closely to the present specimens.

As regards the first pair of legs, Dana's specimens have the arm and hand both longer than the wrist, while in mine the arm is equal to the wrist and the hand shorter.

Palæmonella tridentata, Borradaile, is very closely allied to *P. tenuipes*. Borradaile gives the following points of difference:—

(1) There are three teeth on the underside of the rostrum, instead of two.

(2) The inner edges of the fingers of the second pair of chelæ are armed with teeth.

(3) The distal end of the merus is rounded in profile, but provided with a large spine below at a short distance from the end. In *P. tenuipes* it is acute in profile and without the tooth.

(4) The arrangement of teeth on the inner ramus of the mandible is different in the two species.

Of these differences, number one is merely an individual variation, and numbers two, three, and four apply also to the present specimens and to

Nobili's as distinct from Dana's. The most important difference between the present specimens and *P. tridentata* is brought out in the table of measurements of the second pair of legs given above. In my specimens, and also in those examined by Dana and Nobili, the merus is longer than the carpus. In Borradaile's figure of *P. tridentata* it is shown as considerably *shorter* than the carpus. On the other hand, the proportions of the joints of the first legs in *P. tridentata* agree closely with the present specimens.

As a result of the above considerations, it follows that the present specimens belong to the same species as those examined by Nobili and referred by him to *P. tenuipes*, Dana. I accept Nobili's identification. *P. tridentata*, Borradaile, is closely allied to *P. tenuipes* and doubtfully distinct.

Distribution. Previously recorded from the Red Sea by Nobili; Sulu Sea (Dana); Japan (Ortmann); Maldives (Ortmann); Amboina (De Man).

Genus PERICLIMENES, *Costa.*

PERICLIMENES PETITTHOUARSII (*Audouin*, 1826).

Palæmon petitthouarsii, Audouin, 1826, Descr. Egypte, Hist. Nat. I. iv. p. 91; Savigny, Atlas, Crust., pl. 10. fig. 3.
Periclimenes petitthouarsii, Borradaile, 1898 *b*, p. 381; and 1917, p. 369.

Localities. Station V. A, one, 16 mm. Station V. C, two, 13 and 15 mm. Station VII. E, one, 11 mm. Station VII. C, four, 10–15 mm.

Sudan Coast, no definite locality, forty, 7–18 mm.

Distribution. Previously recorded from the Red Sea by Audouin, Paulson, Kossmann, and Nobili, and by the latter from the Persian Gulf.

PERICLIMENES CALMANI, n. sp. (Pl. **27.** fig. 11; Pl. **28.** figs. 14–15.)

Locality. Sudan Coast, four specimens, 13–17 mm.

Description. The carapace is smooth, without supra-orbital spines. Antennal and hepatic spines are present, the latter a little below the level of the former.

The rostrum (Pl. **27.** fig. 11) reaches almost or quite to the apex of the antennal scale and considerably beyond the apex of the antennular peduncle. It is concave from the base and bears dorsally 8–9 teeth, the proximal tooth well behind the orbit, the second tooth placed over the orbit, and the remainder more or less regularly spaced with a longer interval between the 5th and 6th tooth. The lower edge bears 4–5 teeth, the proximal one below the 5th tooth of the upper edge.

The third maxillipeds reach to the end of the antennal peduncle. The exopod is longer than the antepenultimate joint. The latter bears six spinules and a few setæ on its outer margin. The first legs (Pl. **28.** fig. 14) extend forwards to the apex of the antennal scale. The carpus is about one-sixth longer than the merus and one and a half times the length of the hand. The palm is equal in length to the fingers. There are no ischial, meral, or carpal spines. The fingers are without teeth on their cutting-edges. The second legs (Pl. **28**. fig. 15) extend beyond the antennal scale by one-half of the carpus plus the whole of the hand. The proportions of the joints are as follows:—Ischium 2·0 mm., merus 2·3 mm., carpus 2·55 mm., palm 1·8 mm., finger 1·6 mm. There are no ischial, meral, or carpal spines. Both the fixed and immovable fingers have on their inside margins a shallow oval pit bounded by small teeth proximally and distally.

This species clearly belongs to the subgenus *Falciger*, and if we attempt to run it down with the aid of Borradaile's key to the species of the subgenus we find that it would fall in Section I. by reason of the oval pits in the fingers of the large chela, a peculiarity only noted in two of the species, *P. spiniferus*, De Man and *P. petitthouarsi* (Audouin). From the former species, *P. calmani* is distinguished by the absence of supra-orbital spines and from the latter by the long and slender form of the great chela, the much greater length of the carpus of these limbs, and the absence of spines on the first and second legs.

It is possible, however, that the oval pits have been overlooked in other species of the genus. If, therefore, we ignore Section I. of Borradaile's key and proceed to Section II., we find the nearest ally of *P. calmani* in *P. seychellensis*, Borradaile, from which it is distinguished by the shorter rostrum and the longer pair of second legs.

P. calmani is very closely similar to *P. demani*, Kemp, 1915*a*. The general form of the body and the proportions of its various parts are very much alike. But *P. demani* has a supra-orbital spine and has meral and carpal spines on the second legs. Judging from Kemp's figure, *P. demani* also has oval pits on the fingers of the chelæ of the second pair of legs.

PERICLIMENES sp.?

Localities. Station V. C, two, 7–10 mm. Station VII. A, one, 7 mm.
Uncertain, one, 13 mm.

These specimens belong to the subgenus *Falciger* and to that group of the species having a supra-orbital spine. The rostrum is longer than the antennular peduncle and subequal to the antennal scale. The formula is $\frac{7-8}{2}$, and the rostrum is concave from the base. Unfortunately the second legs are missing in all the specimens. I think they are almost certainly the form recorded from the Red Sea by Nobili under the name of *P. ensifrons*, Dana, but as the second legs provide the characters for specific determination it is not advisable to name these specimens.

PERICLIMENES sp. ?

Locality. Uncertain, one specimen, broken, labelled "Commensal, P.O.13."

Remarks. I cannot identify the single mutilated specimen with any described species and I think that it represents a new form. As the second pair of legs and the posterior half of the abdomen are missing, I refrain from giving it a name. Among described forms it appears to be most closely allied to *P. borradailei*, Rathbun = *P. tenuipes*, Borradaile, nec Holmes, and to *P. kolumadulensis*, Borradaile, 1915.

The rostrum, which is slender and slightly recurved at the tip, extends beyond both the antennular peduncle and the antennal scale, and is one and a quarter times as long as the carapace measured dorsally. The rostral formula is $\frac{1+7}{2}$. The carapace bears supra-orbital, antennal, and hepatic spines. Such of the legs as remain still attached to the specimen are exceedingly long and slender. The first pair extend beyond the apex of the rostrum by the whole of the chela. The carpus is one and a quarter times as long as the chela. The fifth leg reaches forward as far as the apex of the antennal scale. This specimen differs from both *P. borradailei* and *P. kolumadulensis* in the shorter rostrum and different rostral formula and in the presence of a supra-orbital spine, but resembles both in the slender form of the legs.

PERICLIMENES sp. ?

Locality. Station VII. C, one specimen, 9 mm.

Remarks. This specimen cannot be identified with certainty as the second pair of legs is missing. It belongs to the subgenus *Falciger* and to that group of species having antennal and hepatic, but no supra-orbital, spines on the carapace. The suborbital angle of the antero-lateral border of the carapace is acute but not spiniform, and the lower angle sub-rectangular. The rostrum is long, equal in length to the dorsal line of the carapace from the border of the orbit, and extends forward to the same level as the tip of the antennal scale and far beyond the antennular peduncle. It bears seven teeth (including the terminal one) on the upper margin and two teeth on the lower. All the upper teeth are situated on the rostrum itself, the first one immediately above the orbital border, and there are none on the carapace. The antennal scale is about three and a half times as long as broad at its widest part, and the external margin ends in a strong spine which extends beyond the apex of the scale. The antennular peduncle reaches forward to the level of the fifth tooth of the rostrum. It has one spine only on the external distal corner of the basal joint and a prominent spine on the ventral surface of this joint near the middle of the outer margin. The last three thoracic legs seem unusually stout.

The species of this genus are difficult to determine in the absence of the second pair of legs, and I have not attempted a specific identification in this case.

PERICLIMENES sp.?

Locality. Station VII. A, one, 5 mm.

Remarks. This small specimen belongs to the subgenus *Cristiger* and is most closely allied to *P. potina*, Nobili. The rostral formula is $\frac{4}{1}$ and all the teeth are on the rostrum, none on the carapace behind the orbit. There is no supra-orbital spine.

Genus HARPILIUS, *Dana*, 1852.

The type species of the genus is *Harpilius lutescens*, Dana, and Borradaile, on the evidence of Sollaud (1910) that the third maxilliped in this genus has no arthrobranch (although Sollaud does not say what species he has examined), coupled with the remarkable form of the second maxilliped figured for the type species by Dana, has instituted a new genus *Harpiliopsis* to include two species, *H. beaupresi* and *H. depressus*, which have the second maxillipeds of normal form and arthrobranchs on the third maxillipeds. The validity of the genus *Harpiliopsis* seems to me to be questionable. The addition of a single line to Dana's figure (the line showing the contour of the antepenultimate joint) will give a form of second maxilliped not unlike that depicted by Borradaile for *H. depressus*. It is more reasonable to imagine that this line has been accidentally omitted from Dana's figure than to suppose that *H. lutescens* really has the remarkable form of second maxilliped actually figured. *H. lutescens* is otherwise so closely similar to *H. depressus* as to be doubtfully distinct. The latter species has normal second maxillipeds, and on Borradaile's evidence as well as my own, has an arthrobranch on the third maxilliped. So that if my suggestion as to Dana's figure be accepted, *Harpiliopsis* at once becomes a synonym of *Harpilius*.

On the other hand, specimens which I have referred to *H. gerlachei*, Nobili, do not appear to possess an arthrobranch on the third maxillipeds, and they further differ from all the other species of the genus in the absence of a hepatic spine. It would appear therefore that if a new genus is required, it must be instituted to receive *H. gerlachei*. Until more evidence is forthcoming as to what species of *Harpilius* Sollaud has examined with reference to the presence or absence of arthrobranchs on the third maxillipeds, it would be premature to define a new genus for *H. gerlachei* and I prefer, at present, to include all the species in one genus.

HARPILIUS BEAUPRESI (*Audouin*, 1826, Descr. Egypte, Hist. Nat. I, 4, p. 91, pl. 10. fig. 4). (Pl. **28**. fig. 8.)

H. beaupresi, Borradaile, 1898 *b*, p. 386; and 1917, p. 379.
H. beaupresi, Nobili, 1906 *a*, p. 63.

Locality. Suakin, Station VII. A, five specimens, 10–16 mm.

Remarks. The rostral formulæ of the specimens are $\frac{7}{4}$, $\frac{5}{3}$, $\frac{5}{3}$, $\frac{5}{2}$, and $\frac{5}{2}$. All these specimens have a spine on the lower surface of the basal joint of the antennular peduncle. Nobili was unable to find a similar spine in the specimens he examined. *H. beaupresi* is at once distinguished from the other species of the genus by the extreme length of the spine on the outer corner of the joint from which the antennal scale springs. The form of the dactylus (Pl. **28**. fig. 8) of the last three pairs of legs is characteristic. It is stout, slightly curved, swollen at the base, and equal in breadth at its base to the propodus to which it is attached.

Savigny's original figure shows the form of the dactylus very well, but I refigure it here to compare with other species of the genus.

Distribution. Previously recorded from the Red Sea by Audouin, Heller, Paulson, and Nobili; Persian Gulf (Nobili); East Indies (De Man).

HARPILIUS DEPRESSUS (*Stimpson*). (Pl. **28**. fig, 7.)

Harpiliopsis depressus, Borradaile, 1917, p. 380.

Locality. Station VII. C, 1 ♀, 18 mm.

Remarks. The identification of this specimen is based on Borradaile's monograph (1917), but I am doubtful of the distinctness of this species from *H. lutescens*, Dana. Except for the fact that this specimen has two teeth on the lower margin of the rostrum, I can find no marked character in which it differs from Dana's species. The discrepancy in the form of the second maxilliped I have already attempted to explain. The present specimen has an arthrobranch on the third maxillipeds. It is to be noted in this connection that Nobili records Dana's species from the Red Sea, without comment.

The species differs from *H. beaupresi* in its more robust form, in the shorter spine on the outer corner of the joint bearing the antennal scale, in the shape of the antepenultimate joint of the third maxilliped, and in the stouter form of the last three pairs of thoracic legs and their dactyli. The latter are short, stout, and curved, and apparently capable of being almost retracted into a socket at the base of the propodus (Pl. **28**. fig. 7). The whole arrangement recalls the claws of the carnivora and is found in *H. lutescens*, *H. depressus*, *H. gerlachei*, and *H. consobrinus*. In *H. beaupresi* the last thoracic legs are much more slender, and there does not appear to be a socket at the apex of the propodus for the retraction of the claws.

On the ventral surface of the thorax, between the bases of the first pair of legs there is a strong median forwardly directed spine, and in front of the bases of the third pair of legs are two transverse chitinous ridges or plates, one on each side, meeting in the centre and separated by a notch. These latter are exactly in the situation occupied by the thelycum of the Penæidæ, but I have no idea whether they function as such in this species or are even homologous. I have noticed similar structures in *H. gerlachei*.

Distribution. Indo-Pacific, in corals. New to the fauna of the Red Sea. *H. lutescens* is known from Tongatabu (Dana) and the Red Sea (Nobili).

HARPILIUS GERLACHEI, *Nobili*, 1905 *a*, p. 160. (Pl. **28**. fig. 9.)

H. gerlachei, Nobili, 1906 *b*, p. 45, pl. 6. figs. 10, 10 *a*; Borradaile, 1917, p. 381.

Locality. Station V. E, 3 ♀ with eggs, 14–18 mm.

Remarks. These specimens are in substantial agreement with Nobili's description and figures. The rostrum reaches to about the level of the apex of the antennal scale and has the formula $\frac{4-5}{1}$, all the teeth being on the rostrum and none on the carapace. This species is characterized by the absence of a hepatic spine, which together with its tumid form and the shape of the dactyli of the last three pairs of legs serve to render it easily recognizable. The dactylus of the last three pairs of legs (Pl. **28**. fig. 9) is short, stout, strongly curved, and much narrower at its base than the distal extremity of the propodus, which is swollen slightly and appears to have a socket at its apex into which the dactylus can be retracted.

Distribution. New to the fauna of the Red Sea. Otherwise only known from the Persian Gulf (Nobili).

Genus CORALLIOCARIS, *Stimpson*, 1860.

CORALLIOCARIS SUPERBA (*Dana*, 1852, p. 573, pl. 37. figs. 2 *a–f*).

See Borradaile, 1898 *b*, p. 385, and 1917, p. 383.

Locality. Station V. E, 2 ♀ with eggs, 18 and 23 mm.

Remarks. This species has no hepatic spine on the carapace.

Distribution. Previously recorded from the Red Sea by Paulson and Nobili; East Indies; Tongatabu; Tahiti.

CORALLIOCARIS LUCINA, *Nobili*, 1901, p. 5.

C. lamellirostris, De Man, 1902, p. 842, pl. 26. fig. 55.
C. lucina, Nobili, 1906 *a*, p. 57; Borradaile, 1917, p. 384.

Locality. Station V. E, two specimens, 17 and 18 mm.

Remarks. These specimens agree closely with the descriptions given by De Man and Nobili. The only difference I can find from De Man's figures is that there is a greater interval between the fifth (penultimate) tooth of the rostrum and the small sixth (last) tooth, which is much nearer the apex of the rostrum in my specimens. The rostrum extends forward to the apex of the antennal scale and has the formula $\frac{6}{4}$. All the teeth are situated on the rostrum and none on the carapace. This species possesses both antennal and hepatic spines on the carapace.

Distribution. Only known from the Red Sea (Nobili) and Ternate (De Man).

Genus Anchistus, *Borradaile*, 1898 *b*.

Anchistus miersi (*De Man*, 1888, p. 274, pl. 22. figs. 6–10).

See Borradaile, 1917, p. 388.

Locality. Station VII. G, 16 specimens, ♂, 15–21 mm., ♀, 21–30 mm.

Distribution. Previously recorded from the Red Sea by Nobili; Persian Gulf (Nobili); coasts of India (Henderson), and the Mergui Archipelago (De Man).

Anchistus inermis (*Miers*), 1884, p. 291, pl. 32. fig. B. (Pl. **27**. fig. 4.)

A. inermis, Borradaile, 1898 *b*, p. 387; and 1917, p. 388.

Locality. Station VII. G, 1 ♂, 24 mm.

Remarks. The first legs present a feature not hitherto noticed in this species. The chela has the appearance of a somewhat deep spoon or scoop, the edge of which is fringed with somewhat long setæ (Pl. **27**. fig. 4). This appearance is brought about by the expansion of the propodus and the folding inward of its margin. This character is possibly sexual.

Nobili (1906 *a*) in recording *Pontonia pinnæ*, Ortmann, from the Persian Gulf, ascribes to his specimens two characters which do not agree with Ortmann's original description. He says that the rostrum extends 'almost to the end of the antennular peduncle, and that the fingers of the great chela are a little longer than the half of the palm, rather more than one-third of the total length of the hand. Ortmann shows the rostrum to be considerably shorter than the antennular peduncle and, while giving no proportions in his short description, figures the fingers of the great chela of the second pair of legs as scarcely more than one-third of the length of the palm. It is precisely in these two characters that *Anchistus inermis*, Miers, differs from *Pontonia pinnæ*, Ortmann. I think it is very probable that Nobili's specimens from the Persian Gulf, recorded as *Pontonia pinnæ*, Ortmann, should be referred to *Anchistus inermis*, Miers. There remains the question as to whether *Pontonia pinnæ*, Ortmann, is really distinct from *Anchistus inermis*, Miers. The differences between the genera lie entirely in the characters of the third maxilliped. In *Anchistus*, the last two joints are narrow, while in *Pontonia* they are broad. Ortmann makes no mention of the form of the maxillipeds in his specimens. No one except Nobili has recorded his species since. I have given reasons above for supposing that Nobili's specimens were really referable to *A. inermis*, Miers. The two characters of the rostrum and large chela I have already mentioned provide the only points of difference between the two species. Are these sufficient for specific differentiation? An examination of Ortmann's type is necessary to clear up this point.

Distribution. New to the fauna of the Red Sea; hitherto known from the Indian Ocean.

Genus CONCHODYTES, *Peters*, 1851.

CONCHODYTES MELEAGRINÆ, *Peters*, 1851.

C. meleagrinæ, Borradaile, 1917, p. 393.

Locality. Uncertain. 40 specimens, 12–30 mm., labelled "Commensal P.O. 13."

Distribution. Previously recorded from the Red Sea by Nobili; Indo-Pacific in *Meleagrina* and occasionally in *Tridacna*.

Subfamily PALÆMONINÆ.

Genus LEANDER, *Desmarest.*

LEANDER TENUICORNIS, *Say*, 1818, p. 249.

Leander natator, Nobili, 1906 *a*, p. 74.
Leander tenuicornis, Stebbing, 1914 *a*, p. 288.

Locality. Station II, 1 ♀, 37 mm.

Remarks. My specimen agrees very closely with figure 6, pl. 128, of the 'Challenger' Report except that the rostral formula is $\frac{9}{7}$, two of the dorsal teeth being situated behind the orbit. The rostrum extends just beyond the apex of the antennal scale and is of the deep "latirostris" form. The confusion which at present exists among the species of this family is well exemplified in the species here in question. Stebbing (*loc. cit.*) has identified the *Leander natator* of Milne-Edwards and subsequent authors with the earlier described *Palæmon tenuicornis* of Say. At the same time Stebbing points out that this species agrees with *Leander squilla* in having the palp of the mandible two-jointed. His description runs as follows: "the mandibles have a very slender two-jointed palp, the second joint much the longer." My specimen agrees exactly with this description. It should, however, be pointed out that specimens in the British Museum labelled *Leander natator* have, according to Calman (Kemp, 1910, p. 130, footnote), a three-jointed mandibular palp. Spence Bate (1888, p. 784) makes no mention of the number of joints in the palp but merely remarks on its "extreme tenuity." The question is of great importance in connection with the characters of the genus *Leander*. The type of the latter genus is *L. erraticus*, Desmarest, identified by Spence Bate and later authors with *L. natator*, M.-Ed., which, as mentioned above, Stebbing has shown to be identical with *L. tenuicornis* of Say. Stimpson also gives *L. natator* as the type species. It follows, therefore, that the type species of the genus *Leander* has a two-jointed palp, and if the number of joints in the mandibular palp be considered of generic importance, it is the three-jointed palp species which must be transferred to a new genus.

Palæmon torensis, Paulson, cannot be identical with *L. natator*, M.-Ed., as surmised by Nobili, since Paulson distinctly figures the mandibular palp as three-jointed. On the other hand, *Palæmonella gracilis*, Paulson, is a species of *Leander* with a two-jointed mandibular palp.

These remarks will serve to show the pressing need for a revision of the genera and species of this family.

Distribution. Widely distributed in the Atlantic, Mediterranean, Indian, and Pacific Oceans.

LEANDER CONCINNUS (*Dana*, 1852, p. 587, pl. 38. fig. 10).

Leander longicarpus, Ortmann, 1891, p. 516.
Leander concinnus, De Man, 1897, p. 765.
Leander concinnus, De Man, 1902, p. 807.

Locality. Station I. A, 23 specimens, the largest 38 mm. in length.

Remarks. The rostrum in the majority of the specimens has the form shown in Dana's figure 10 *b*. There is in all the specimens but a single tooth behind the orbit. This is followed by from 4–6 teeth more or less equidistantly placed on the proximal part of the rostrum. The distal part is upcurved slightly, and usually devoid of teeth with the exception of a small one almost at the extreme apex, giving the latter a bifid appearance. In two specimens the apex is trifid, and in one of the remaining specimens there is a single tooth on the distal part of the rostrum half-way between the proximal teeth and the apex. Below, the rostrum bears from 3–5 teeth. The rostral formula may therefore be represented as follows :—

$$\frac{1+(4\text{–}6)+(0\text{–}1)+\text{bifid (trifid) apex}}{3\text{–}5}.$$

This species, like the preceding one, has the palp of the mandible two-jointed.

Distribution. New to the fauna of the Red Sea. Fiji (Dana) ; East Indian Archipelago (De Man).

Super-family Crangonoida.

Family PROCESSIDÆ.

Genus NIKOIDES, *Paulson*, 1875, p. 98.

NIKOIDES sp.?

Locality. Station VIII. C, one specimen, 8 mm.

Remarks. I am unable to determine this specimen with any degree of certainty, and as the left leg of the first pair and both legs of the second pair are broken it is not possible to give an adequate description. It differs from the description of *N. danæ*, Paulson, as given by Nobili in the following particulars :—

(1) The rostrum is very much shorter, hardly extending as far forward as the proximal margin of the cornea of the eye ; it is acute with a single small acute dorsal tooth quite near the apex ; on each side of the base of this tooth there springs a single strong seta which extends forward to the apex of the rostrum.

(2) The exopod of the first pair of walking legs is very much shorter and barely extends beyond the ischiopodite.

(3) There are no spines on the ischius and merus of the last three pairs of legs, which are otherwise in close agreement with Nobili's description.

In the last two characters my specimen approaches *N. maldivensis*, Borradaile, 1915, p. 209, but I am unable to institute a comparison with that species in the characters of the first legs, and Borradaile's description of the rostrum of *N. maldivensis* does not agree with what I have observed in the present specimen.

The chelate leg of the first pair, which is present in my specimen on the right side, agrees closely with Nobili's description of that appendage in *N. danæ*.

Suborder **REPTANTIA.**

Tribe **ANOMURA.**

Super-family **Thalassinidea.**

Family AXIIDÆ, *Bate*, 1888.

Genus AXIOPSIS, *Borradaile*, 1903, p. 538.

AXIOPSIS ÆTHIOPICA, *Nobili*, 1904, p. 235.

A. æthiopica Nobili, 1906 *a*, p. 93, pl. 6. fig. 1.

Locality. Station V. E, one specimen, 19 mm.

Remarks. This specimen agrees completely with Nobili's careful description, and I have nothing further to add to his account.

Distribution. At present only known from the Red Sea (Nobili).

Family CALLIANASSIDÆ, *Bate*, 1888.

Subfamily UPOGEBIINÆ, *Borradaile*, 1903, p. 542.

Genus UPOGEBIA, *Leach*.

UPOGEBIA (CALLIADNE) SAVIGNYI, *Strahl*, 1862, p. 1064.

U. savignyi, Nobili, 1906 *a*, p. 98.

Localities. Station VII. D, 29 specimens, 5–27 mm. Station I. C, always in pairs, a large ♀ and small ♂ in yellow sponge, 14 specimens. Station V. G, one specimen, 9 mm.

Uncertain. 1 juv., 5 mm., labelled "Crust. fr. 44."

Remarks. This species seems to be usually, if not always, associated with sponges. Two specimens were infected by a Rhizocephalan parasite on the under side of the abdomen.

UPOGEBIA (UPOGEBIA) PSEUDOCHELATA, n. sp. (Pl. **28**. figs. 16–22.)

Locality. Station VII. C, 1 ♂, 6 mm., 1 ♀, ovigerous, 12 mm.

Description. The rostrum is quite short and does not extend beyond the eyes. In dorsal view it is triangular in shape with an obtusely rounded apex, and its margins are not provided with teeth or spines. The lateral tooth on each side is almost obsolete, but it marks the anterior termination of a strong lateral tuberculated ridge which runs backward on each side to the well-marked cervical groove. This ridge bears about a dozen small tubercles. The central portion of the dorsal surface of the rostrum and carapace is provided with numerous small obscure tubercles arranged irregularly in six rows, more numerous and prominent nearer the rostrum, becoming obsolete or absent towards the cervical groove. Between the tuberculated portion of the carapace and the lateral ridge on each side, and running parallel to the latter, is a linear groove or impression, devoid of tubercles and likewise becoming obsolete as it nears the cervical groove. The rostrum itself is provided with a dense tuft or mass of short setæ, and the remaining part of the carapace and the body is adorned with scattered hairs of varying lengths. The antennular peduncle (Pl. **28**. fig. 17) is shorter than the antennal peduncle, equal in length to the first three joints of the latter, and extending beyond the eye by the whole of the last two joints and the narrow distal portion of the basal joint. The third segment is three times the length of the second. One flagellum is thirteen-jointed and the other ten. The longer flagellum is about one-fifth longer than the peduncle, the shorter flagellum equal to the peduncle in length.

The antennal peduncle (Pl. 28. fig. 16) is composed of four segments with no prominent spines on any of them. Between the second and third segments there is the articulated remnant of the antennal scale, consisting of a small triangular plate with two small apical teeth. The second joint is furnished with a row of very long setæ on the whole of its lower margin. This row of setæ is continued across the outer face of the third joint and terminates in a dense brush on the upper distal corner of the joint.

The first pair of legs (Pl. 28. fig. 18) are equal in size and subchelate in both sexes. The merus is equal in length to the propodus and double the length of the carpus. The propodus or palm is three times as long as wide, oblong in shape with parallel sides. The movable finger is about half as long as the palm, and the fixed finger rather less than half the length of the movable one. The fixed finger bears five small tubercles on its proximal half and impinges on a prominent tooth on the movable finger so that a false chela is thereby formed. There are no prominent spines on any of the joints but the limb is richly provided with setæ. The merus has a row of very long setæ on its inner and lower margin, while the carpus has a dense fringe of small hairs on its upper margin. The palm has its lower margin fringed with long setæ, and there is a dense row of shorter hairs on its outer face besides other scattered hairs. The movable finger is well provided with setæ.

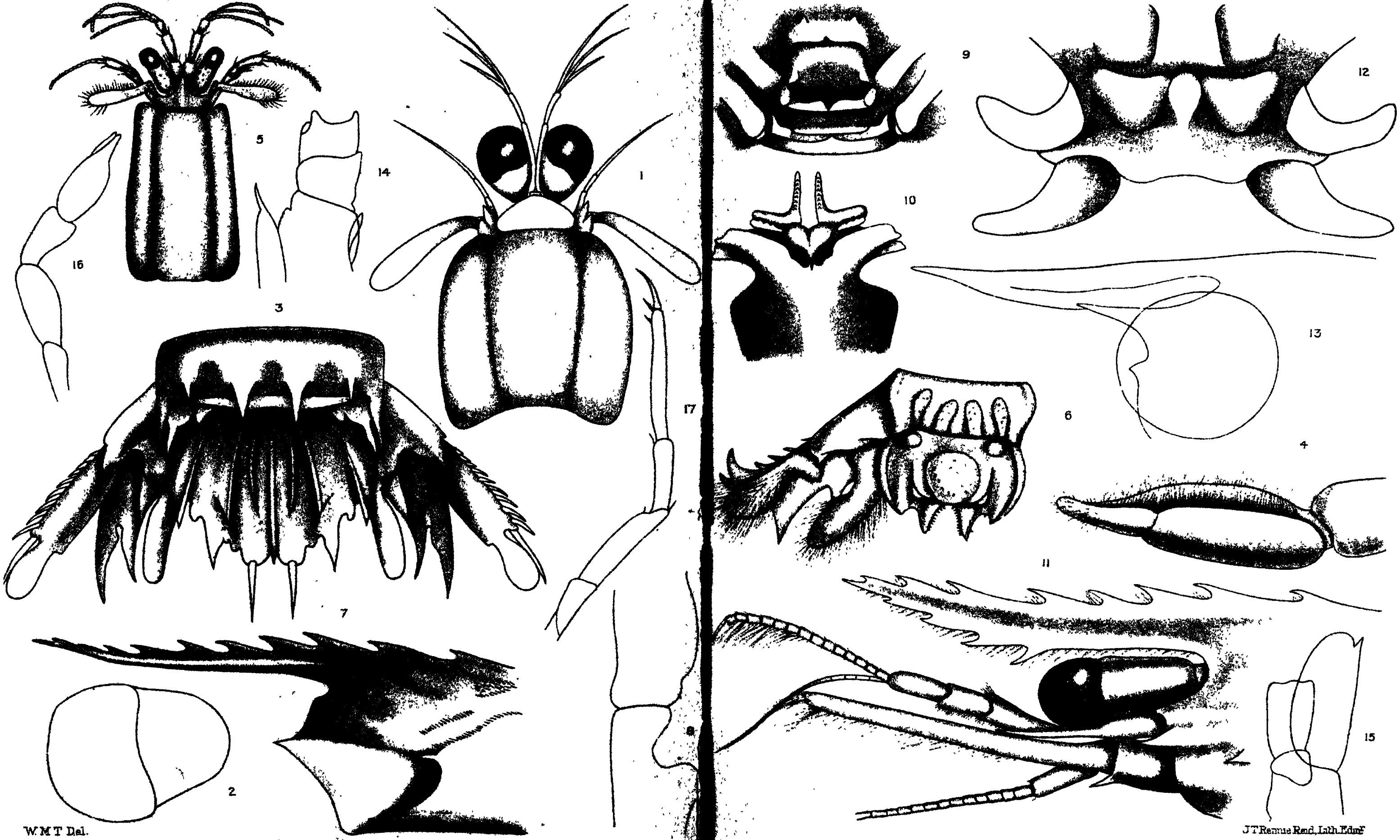
The second leg (Pl. 28. fig. 19) has the merus about equal to the propodus and carpus combined, the proportions of the joints being merus 3·75, carpus 1·75, propodus 2, dactylus 1. The propodus is two and a half times as long as broad. There are no specially prominent spines on these legs, but the merus, carpus, and propodus are well provided with long setæ.

The third and fourth legs (Pl. 28. fig. 20) are specially noticeable for the form of the dactylus. Its outer margin bears five to seven tubercles and the inner margin a dense saw of about 14–16 finely pointed teeth on the distal part.

The fifth legs (Pl. 28. figs. 21–22) have the usual subchelate arrangement due to a prolongation forward of the lower edge of the propodus. This prolongation is about half as long as the dactylus and terminates in a prominent tooth. The dactylus bears a saw of fine teeth on its inner margin. The telson is broader than long, its lateral margins parallel, the lateral corners evenly rounded and the posterior margin straight. It is of the same length as the uropods.

Length of an ovigerous female, 12 mm., of the only male, 6 mm. The male specimen agrees fully with the female, but I am unable to say whether there is the marked sexual dimorphism in size which the two specimens suggest.

Among described species, *U. pseudochelata* approaches most nearly to *U. heterocheir*, Kemp, 1915 *a*. The latter has the same pseudochelate form



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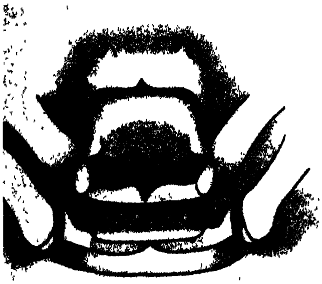
J. T. Rennie Reid, Lith. Edinr.

STOMATOPODA AND MACRURA DECAPODA FROM RED SEA.



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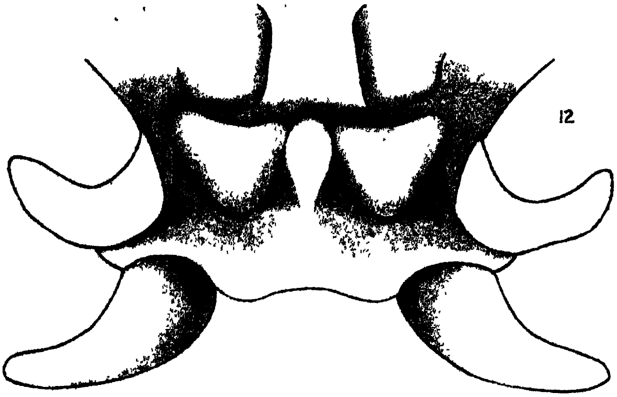

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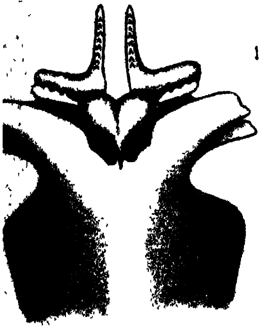

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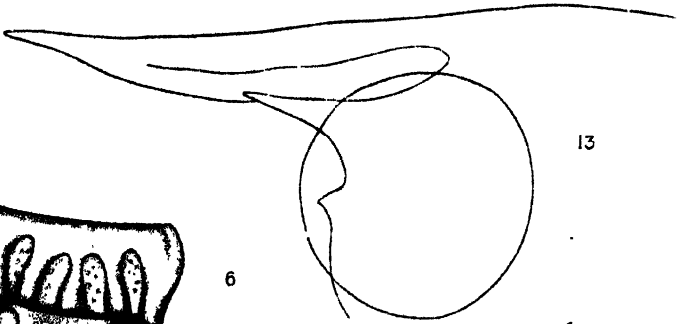

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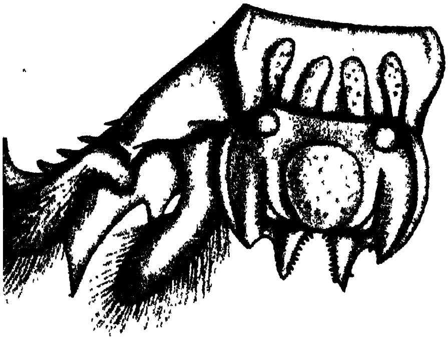

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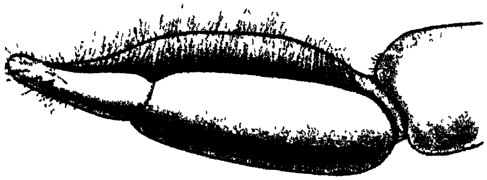

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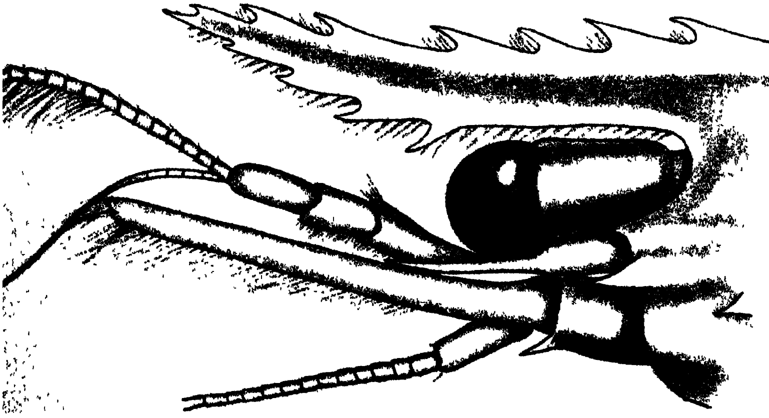

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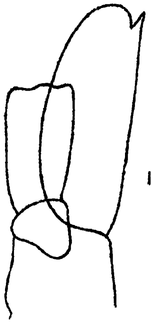

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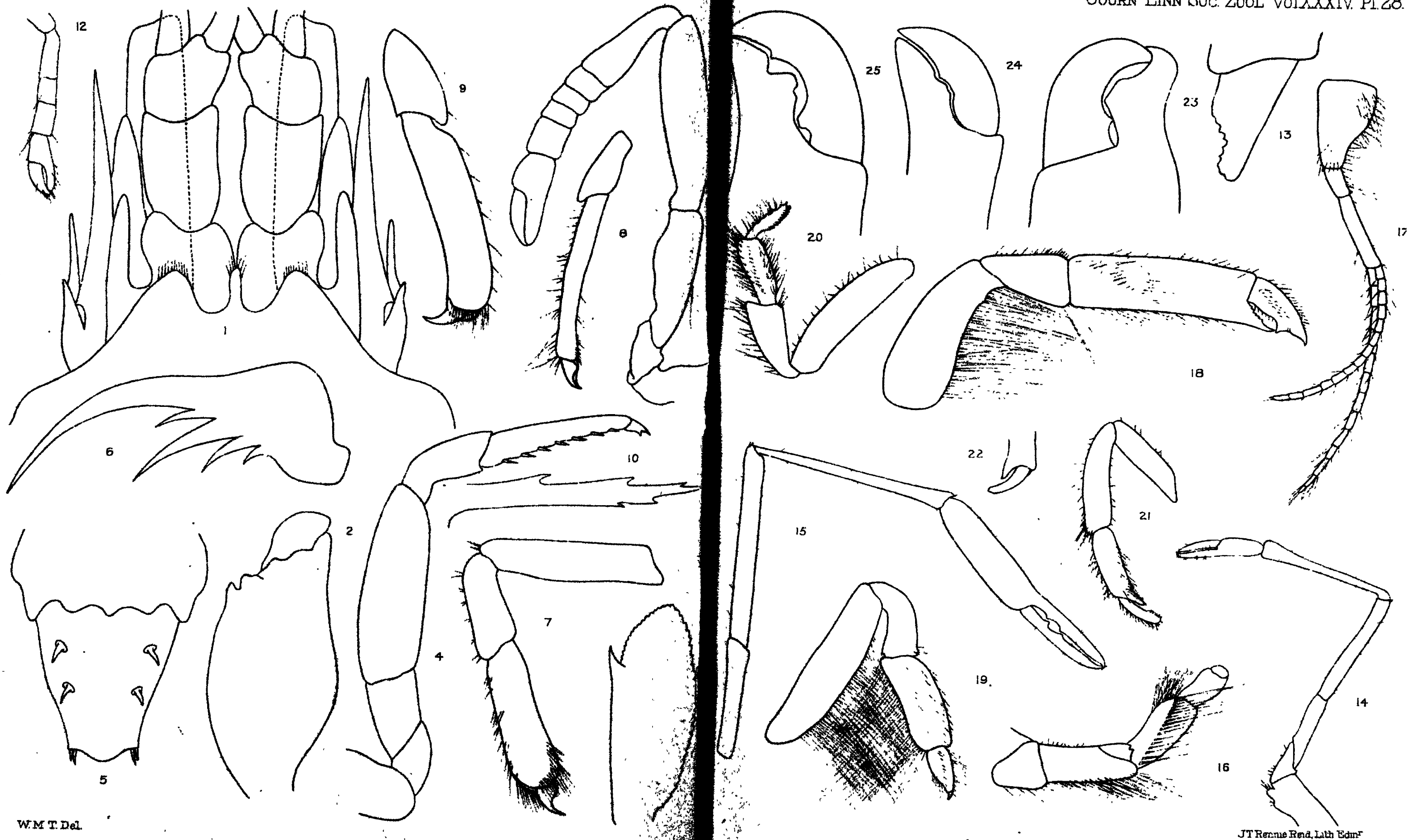
J.T. Rennie Reid, Lith. Edinr

DECAPODA FROM RED SEA.

Tattersall

Journ Linn Soc. Zool Vol XXXIV. Pl.28.



W.M.T. Del.

J.T. Rennie Reid, Lith Edinr

STOMATOPODA AND MACR DECAPODA FROM RED SEA.

of the first pair of legs in the male only, the female having the first pair of legs simple. In this character the species are distinct. These two species also agree in the character of the dactyli of the third and fourth pairs of legs. *U. pseudochelata* differs from *U. heterocheir* in the following points:—(i.) the much shorter rostrum and the almost complete absence of lateral teeth; (ii.) the presence of tubercles on the rostrum; (iii.) the relatively longer flagella to the antennule; (iv.) the absence of spines and teeth on the limbs and other appendages; (v.) the different form of the pseudochelate limb and the fact that it is common to both sexes; (vi.) size.

In general facies and structure the two species are closely allied, but the differences already mentioned may be considered of specific value.

EXPLANATION OF THE PLATES.

PLATE 27.

Fig. 1.	*Pseudosquilla megalophthalma*, Bigelow.	Dorsal view of anterior region.
2.	" "	Lateral view of eye to show the real proportion between cornea and peduncle.
3.	" "	Dorsal view of sixth abdominal segment and telson.
4.	*Anchistus inermis* (Miers).	Chela of leg of the first pair of the male.
5.	*Gonodactylus brevisquamatus*, Paulson.	Dorsal view of anterior region of specimen 28 mm.
6.	" "	Dorsal view of sixth abdominal segment and telson of the same specimen.
7.	*Penæopsis stebbingi* (Nobili).	Carapace and rostrum.
8.	" "	Merus of last thoracic leg of a male to show notch.
9.	" "	Thelycum.
10.	" "	Petasma.
11.	*Periclimenes calmani*, n. sp.	Lateral view of anterior end.
12.	*Penæopsis vaillanti* (Nobili).	Thelycum.
13.	*Athanas crosslandi*, n. sp.	Lateral view of anterior end to show the relations of the rostrum, extra- and infra-corneal spines, and eyes.
14.	" "	Antennular peduncle.
15.	" "	Antennal peduncle and scale.
16.	" "	Leg of the first pair.
17.	" "	Leg of the third pair.

PLATE 28.

Fig. 1.	*Synalpheus quinquedens*, n. sp.	Dorsal view of anterior end.
2.	" "	Large chela.
3.	" "	Leg of the second pair.
4.	" "	Leg of third pair.

Fig. 5.	*Synalpheus quinquedens*, n. sp.	Dorsal view of sixth abdominal segment and telson.
6.	*Lysiosquilla multifasciata*, W.-M.	Raptorial claw.
7.	*Harpilius depressus* (Stimpson).	Third leg (distal joints) to show the form of the dactylus.
8.	,, *beaupresi* (Aud.).	Distal joints of third leg to show form of dactylus.
9.	,, *gerlachei.*	Distal joints of third leg to show form of dactylus.
10.	*Hippolyte proteus* (Paulson).	Rostrum.
11.	,, ,,	Antennal scale.
12.	,, ,,	Carpus and chela of the second pair of legs.
13.	*Penæopsis stebbingi* (Nobili).	Lateral view of petasma to show teeth.
14.	,, ,,	First leg.
15.	,, ,,	Second leg.
16.	*Upogebia pseudochelata*, n. sp.	Antennal peduncle.
17.	,, ,,	Antennular peduncle and flagella.
18.	,, ,,	Leg of the first pair.
19.	,, ,,	Leg of the second pair.
20.	,, ,,	Leg of the third pair.
21.	,, ,,	Leg of the fifth pair.
22.	,, ,,	Distal end of leg of the fifth pair.
23.	*Athanas dimorphus*, Ortmann.	Chela of the right leg of the first pair in the male.
24.	,, ,,	Chela of the left leg of the first pair in the male.
25.	*Athanas djiboutensis*, Coutière.	Chela of the right leg of the first pair in the male.

Observations upon the Relationships of the (Bryozoa) Selenariadæ, Conescharellinidæ, etc., Fossil and Recent. By ARTHUR WM. WATERS, F.L.S., F.G.S.

(PLATES 29, 30.)

[Read 19th June, 1919.]

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*IN preparing a list of Bryozoa from Oran (Algiers) a few specimens of *Cupularia Johnsoni*, Busk, have led me to more extended studies for a better understanding of the whole of the group; however, a large number of spirit or fresh specimens are required for a complete study of this little understood group, which is one of the most interesting. This communication makes no pretension to dealing exhaustively with it, being principally remarks on some species in my collection.

I had previously received, from the late Canon Norman, a few spirit specimens of three species of *Cupularia*, collected off Madeira, namely, *C. canariensis*, Busk, *C. Johnsoni*, Busk, *C. Lowei*, Busk, each of which revealed new structures, in stained preparations and sections.

Of what have been considered as Selenariadæ all are more or less cup-shaped or flat, and though now the shape alone would not be considered sufficient for classification, yet it is important to see how far other characters run through all or most species.

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* Shortened references are used in the text for the sake of economy, and the explanations of these contractions are given on p. 409.

The basal* structure of *Cupularia canariensis* has a series of parallel chambers (Pl. 29. fig. 1) filled with a granular substance and having a connection from each chamber to its neighbours through rosette-plates. The lateral walls are parallel with the axis of the zoarium. These chambers are partly shown by Busk in his *L. canariensis*, 'Crag Polyzoa,' pl. 2. fig. 2 *e*, and would have been called kenozooecia by the late Professor Levinsen, while Reuss and others have named the chambers at the base of *Batopora* "abortive cells." In *Cupularia* the walls of these chambers, as well as those of the zooecial and vibracular chambers, are lined by large square flat cells with a small nucleus (Pl. 29. figs. 2 & 3). These large cells seem to occur generally in the Selenariadæ.

In *C. Lowei*, Busk, looking at decalcified and stained preparations, with the opercular wall in focus, a number of small bundles of muscles are seen, which pass from the frontal membrane through the large frontal calcareous pores (Pl. 30. fig. 1). Similar muscles occur generally in the Microporidæ. Looking at the same preparation from below, the zooecial chambers are seen separated by a considerable free space, and to about the median line of the zooecial chamber there is a row of single† muscles, or sometimes a small bundle, passing from the lower surface of the zooecial chamber to the lower surface of the zoarium (Pl. 30. figs. 2 & 3). No structure at all comparable to this has been mentioned as occurring in the Bryozoa; however, the basal calcareous wall gives an indication of their occurrence, by a groove along the line of the muscles, with a pore at the end (Pl. 30. fig. 4); and there is no doubt that fossil *C. umbellata*, Defr., and some other species, had the same muscular arrangement. Further examination of spirit specimens may reveal points which could not be distinguished in the very limited material available.

Whether a new genus should be made before more material and species have been examined is perhaps an open point, though it does not seem that species having such different structures as *C. canariensis* and *C. Lowei* can remain together. If found advisable, *C. Lowei*, *C. umbellata*, etc., might be placed in a new genus. It is the *Discoporella* of d'Orbigny with *C. umbellata* as the type, but the name having long been used, in mistake, for a Cyclostomatous genus it is better dropped.

---

* I shall throughout the paper, so far as possible, consider the colony as seen in the position in which it first grows on its support, so that the opercular wall is the upper surface, while the lower or base rests upon the support in the first stage. In doing this no opinion is pronounced on the suggestion that some mature forms may live in a reversed position, and for the same reason the base of the cone is always shown below, even though possibly it might be more correct to reverse it in the mature forms of some species.

† In a very good specimen the threads to the dorsal surface are fine lines, about the same size as the frontal opesial muscles, but in a specimen in which some changes have taken place they are large and alternately light and dark, that is striated, which may be a histological change. At each end the muscle widens out (as in Pl. 30. fig. 28).

These two structures having been briefly referred to, the Selenariadæ can be considered, and an attempt made to understand the relationship and limitations of the group. In all the growth is from the apex, and in *Cupularia*, *Selenaria*, and *Lunulites* it is known that under the apex there is often a grain of sand, a flake of shell or stone, or very frequently the shell of a foram. This was, so far as I know, first pointed out by Defrance, but has since then been frequently and almost amusingly rediscovered, being alluded to by Michelin, Goldfuss, Reuss, Stoliczka, Busk, Beissel, Gabb & Horn, Waters, Maplestone, Robertson, Canu, and Harmer, though frequently it has been thought to be a characteristic of some one species or genus (see Pl. **29.** figs. 1, 7, 8, 9, 10, and Pl. **30.** figs. 10, 12).

The calcareous shell of the Selenaridan colony usually entirely encloses the hard base on which the growth started, showing no sign of the support either above or below, though sometimes the growth is on a much larger stone, as in some specimens of *Cupularia canariensis* from Petit Tahou, Liberia (Pl. **30.** fig. 12). It would seem impossible for a colony so heavily weighted to float, nor can we think it could float in a reversed position. In *Vibracella trapezoidea*, Reuss, there is in several specimens a small projection on the under surface below the apex, caused by the presence of a very young foram, but a few are found growing on much larger specimens of this *Orbitoides stellata*, Gümb., or, as I am told it ought now to be called, *Orthophragma* (see Pl. **29.** fig. 10). This *Vibracella* grows on the foram, and then grows beyond it, like an inverted cup, though in the specimen figured perhaps simultaneous growth of both organisms had taken place. When I first described * *Vibracella trapezoidea*, Reuss, only small flat pieces were available, but since then a number of disk-like forms, from Bocca di Sciesa, Colle Berici, N. Italy, have been cleaned up, closely resembling in size and shape *Cupularia canariensis*. From the same locality I have a few specimens of *Mamillopora bidentata*, Rss., also with the *Orbitoides* attached to the lower surface, but not centrally, nor have the majority anything attached, so that the few cases are probably accidental. No sand or other support has been mentioned as occurring in *Mamillopora*, *Batopora*, or *Conescharellina*.

Returning to *Cupularia* and *Selenaria*, the larva settles on the support mentioned, and round the primary zoœcia there are in *Cupularia*, and usually in *Selenaria*, eight zoœcia which are much smaller and shallower than the peripheral zoœcia, and often in these smaller zoœcia there is no sign of there ever having been an opercular opening. In *Lunulites* there are six or eight zoœcia surrounding the primary. The growth in the surrounding zoœcia in *Cupularia* is shown in my Pl. 30. fig. 11, and Busk has figured them in *C. Johnsoni* [*], Busk; *Selenaria maculata* seems to have six zoœcia round the primary [†].

---

* "North Italian Bryozoa," Quart. Journ. Geol. Soc. vol. xlvii. p. 11, pl. 1. fig. 23 (1891).

Canu mentions eight zoœcia round the primary in *Lunulites lævigata*, Canu; but some *Lunulites* as *L. sella*, Marsson and *L. Goldfussi*, Hag., have only six. I have figured *Selenaria concinna*, Busk (Pl. 30. fig. 9), showing only five zoœcia, but as there are three vibracular chambers these may be taken as representing three zoœcia. There are various Bryozoa in which the primary is surrounded by eight zoœcia, as *Flustrella hispida*, Fab., from Oban, and as shown by Barrois there are eight zoœcia round the primary in [‡] *Microporella impressa*, Aud., and six in [§] *Membranipora pilosa*, L. In *M. lineata*, L., there are also six, as is the case in *M. nitida*, Johnst., *M. Dumerilii*, Aud., *M. tenuirostris*, Hincks, *Microporella diadema*, MacG., *M. ciliata*, Pall., from Oban, and *M. Malusii*, Aud. These may be taken as typical figures, even if there is some variation. In *Cupularia*, *Selenaria*, and *Lunulites*, the younger zoœcia, sometimes even to three rows round the primary, have a calcareous perforated front, just as we have seen in the ordinary zoœcia of *Cupularia Lowei*, covered on the front by a membrane, to which bundles of muscles passing through the frontal pores are attached to draw it down, so that the structure of these is Microporidan, while the outer zoœcia have a Membraniporidan operculum.

In some Selenariadæ the opercular opening is more or less closed by a tongue-like calcareous projection to which I have referred as occurring in [‖] *Selenaria petaloides* fossil from New Zealand, but in *S. concinna* (Pl. 30. fig. 9) it commences near the proximal end until at last the aperture may be entirely closed. It seems that this closure must be compared with those which I [¶] have described over the operculum of *Schizoporella unicornis* and other Schizoporellidæ, though it takes a rather different form. Maplestone [**] has already referred to it.

---

[*] Quart. Journ. Micr. Soc. vol. vii. pl. 23. fig. 3.

[†] I have made sections of the small (3–6 mm.) fossil *Cellepora globularis*, Rss. from the Bartonian of S. Urbano di Mte. S. Greve, Vicentine, a species described by Reuss from Val di Loute, but in his first description other species were included. Enclosed in the colony, but not in the middle, is a grain of sand without any small zoœcia on it, so that there is no reason for considering that it grew upon the sand or for making any comparison with Selenariadæ. There are two small oral avicularia in the peristomial tube, and this shows it is either *Cellepora* or *Lagenipora*, but no ovicells have been seen.

[‡] Emb. des Bry. pl. 16. fig. 2 (1877).

[§] *Loc. cit.* pl. 15. fig. 9.

[‖] Quart. Journ. Geol. Soc. vol. xxxix. p. 442, pl. 12. fig. 11 (1883).

[¶] Journ. Linn. Soc., Zool. vol. xxxiv. p. 15 (1918).

[**] "Vict. foss. Selenar.," vol. xvi. p. 217, pl. 25. fig. 8 (1904).

APPENDAGES.

The appendages of the group have not received the attention they deserve, and avicularia have frequently been in a wholesale way called vibracula as in *Conescharellina*, which always has avicularia. The vibracula of *Selenaria* are of a type quite different from anything known elsewhere, for they move in a ring external to the vibracular chamber.

In *Lunulites* there are various forms of appendages all of which have been generally spoken of as vibracula, whereas vibracula only occur in a limited number of forms in the family, such as *Vibracella trapezoidea*, Rss., and *Lunulites mitra*, Marsson (probably *Vibracella*). There are "onychocellaires" as figured by Beissel in *L. Goldfussi*,* Hag., also they occur in *L. sella*, Mars., and *L. salebros*, Mars., and probably in *L. Beisseli*, Mars., in which there is an elongate chamber, usually broken down. *L. cupulus*, Busk $=$*L. gibbosa*, Busk, also closely related to *L. patelliformis*, Maplestone (*non* Marsson), has a long tapering seta divided at the end (Pl. **30**. fig. 16), which is different from anything we are acquainted with, and probably must be considered as avicularian.

Lunulites of the *radiata*-type are the most common, and the avicularian chamber has a projection on each side, but being rarely well preserved they have consequently seldom been sufficiently figured. The name *Lunulites* will probably ultimately be confined to this group, which will include such species as *L. Hagenowi*, Bosc (*non* Beissel), *L. transiens*, Gregory, &c.

I † have on several occasions said that the real difference between avicularia and vibracula consisted in the avicularia only having motion in one direction, whereas vibracula have motion in all directions, and we must look at the base of the appendages, or the chamber containing the muscles, &c., to decide which of the two we are dealing with; whereas the length of the appendage has little classificatory value in the Cheilostomata, for short, round, or triangular avicularian mandibles may be replaced by whip-like mandibles, as in *Microporella coronata*, &c.

In *Cupularia canariensis* the central setæ are very short and small, though quite mature, increasing in size to the periphery, where they are very long. Correct appreciation of the differences between the two organs would have led to their being more considered in classification in the present group, as well as in other recent and fossil forms. *Conescharellina* has avicularia, *Cupularia* and *Selenaria* have vibracula, *Lunulites*, as it has been understood, has avicularia, vibracula, and onychocellaires. *Mamillopora* probably always has avicularia. In *Cupularia*, the muscles are frequently attached to the vibracula by broad bands (Pl. 30. fig. 29), instead of by narrow tendons as is generally the case in avicularian mandibles.

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* "Ueber die Bry. der Aachner Kreidebildung," pl. 2. figs. 22, 24. Nat. Verh. Holland. Maat. Wetenschappen, vol. xxii., Haarlem 1865.

† "Bryozoa," Résultats du Voyage du S.Y. 'Belgica' in 1897–8–9, p. 27 (1904).

OVICELLS.

No ovicells are known in *Cupularia*, but ovaria and embryos are found in the zooecia near the periphery (Pl. 30. fig. 25), nor are any known generally in *Selenaria*, though the late C. M. Maplestone, in a letter, wrote that in specimens from Queensland he has seen the ovicells of *S. concinna* resembling those of *Conescharellina philippinensis*. In *Conescharellina philippinensis* there is a raised globular ovicell as described by Whitelegge [*], and I have some in my collection, though, out of some hundred specimens, ovicells have only been seen in two or three. The ovicell, like the operculum, is directed to the centre of the zoarium in a puzzling manner. *Conescharellina eocæna*, Neviani, also has ovicells.

In *Mamillopora simplex*, Kosch., the ovicell is a raised inflation and is widely open, as in *Haloporella*. In *Orbitulipora petiolus*, Lonsd., the ovicell is also globose. Smitt [†] figures it in *Mamillopora cupula*, Sm.; Reuss and I have described it in *Batopora multiradiata*, Rss. "*Cupularia bidentata*," [‡] Rss., also shows an ovicell, but from the figures it was not clear to what genus it belongs, but now it is found to be *Mamillopora*, closely allied to *M. simplex*, Kosch.

Most of the published figures of the earlier authors gave the Selenariadæ upside down, whereas in such genera as *Cupularia*, *Selenaria*, *Lunulites*, the distal end with its Membraniporidan aperture should be shown at the top. Maplestone [||], when dealing with *Conescharellina*, says, in accounting for the position, "the free edge of the operculum is directed towards the apex, but it is not the distal edge. The fact is that the operculum is hinged at the distal end and not at the proximal one; so that in the conical forms not only are the zooecia upside down but the operculum is also upside down." Difficult as it is to understand this reversal it seems to be the case in *Conescharellina*, but not in *Cupularia*, *Selenaria*, or *Lunulites*.

Whitelegge [§], Haswell [¶], and Maplestone [**], call attention to the semilunar slits * which seem to occur quite generally in *C. philippinensis*, and at any rate in most species of *Conescharellina*. They are found in quite young zoaria, and in older ones they may occur in various positions; sometimes in a circle, that is at equal distance from the apex. I have seen in a colony two such circles with several slits, sometimes the slits occur along the radial line of the zoaria, in others between two radial lines.

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[*] "Australian Poly." p. 342. 1887; see also Maplestone's "Biporæ," p. 6, pl. 1. fig. 2 (1910).

[†] Floridan Bryozoa, pl. 2. fig. 33; pl. 7. figs. 146, 147 (1873).

[‡] Waters, "Batopora," p. 87, pl. 6. figs. 7, 11 (1919).

[||] "Growth and Habits of Biporæ."

[§] "Australian Polyzoa," p. 339. 1877.

[¶] "Polyzoa from the Queensland Coast," Proc. Linn. Soc. N.S.W. vol. v. p. 42 (1881).

[**] "Biporæ," p. 5. 1910.

Whitelegge's theory, of these slits being rudiments of intercalated new zoœcia, was declared by Levinsen to be practically impossible, and from the position of these slits it does not seem that they can indicate new zoœcia, also the chambers are smaller and simpler than those of the zoœcia, nor are there so many connections as in the zoœcia. Having a considerable number of good dry specimens of *C. philippinensis*, it was hoped that examination, and sections in various stages, would give an explanation of their function, but this was not easy, though the explanation now offered will, I fully expect, be confirmed when living or spirit specimens are examined.

Conescharellina angulopora (Woods) and *C. flabellaris*, Lev., have a projecting growth at the apex (Pl. **29**. fig. 16; Pl. **30**. fig. 19) giving much the same appearance as the basal end of *Cellaria* and *Tubucellaria*, both of which are directly attached by tubular radicles to the substratum. The slits, if my theory is right, indicate the radicle chamber; and in a large number of Bryozoa radicle chambers may occur with great frequency, even to each zoœcium, though the radicles may be developed in very small numbers. In a previous paper allusion has been made to the radicle chamber in *Catenaria Lafontii* †, Aud., in which a round spot, on the dorsal surface, was shown to each zoœcium by Savigny, Busk, and others, without it being suspected that this was the opening of a dorsal radicle chamber, until I found a specimen with a few radicles,—although I have seen only a few, since they are very rare.

When a radicle is formed in *Conescharellina* probably the disk closing the chamber is absorbed, and then a semicircular opening occurs as in Pl. **29**. fig. 19. *s.s.* Levinsen, p. 310, says "these superficial chambers seen in the whole colony seem to be in mutual connection with each other." They are in communication through rosette-plates.

Some rather important suggestions ‡ have been made that the mature zoarium floats with the apex at the bottom, and we are awaiting proofs as to how this takes place, as it is difficult to understand. Whitelegge*, in a postscript, says that he has had *C. philippinensis* under examination, and that "nearly every specimen possesses a pair of tubular filaments inserted on each side of the zoarium"; also he thinks "the tube appears to grow out of an aviculurium." Will it not be found that they grow from the semilunar slit?

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* Levinsen proposes to speak of lunœcia instead of semilunar slit, but when we have a good name, why do we want to change it, even before the function of the structure is understood? We must resist the tendency to change the name of each minute structure we find. Canu and Bassler say that the lunœcia are openings of "special compensation zoœciules": no proof is given, and I doubt whether it will be found to be the case. See Early Tert. Cheil. Bry. p. 76. 1917.

† "Bry. from Rapallo, &c.," Journ. Linn. Soc., Zool. vol. xxvi. p. 15 (1896).

‡ Maplestone, "Biporæ," p. 3. D'Orbigny, Pal. Franç. p. 447, suggested that the young colonies of *Conescharellina* were perhaps fixed by the conical extremity, and in many cases, at any rate, this seems the most probable.

Harmer †, speaking of the Selenariadæ, says that he has some evidence that they may be attached to the ooze by means of very delicate flexible rooting processes, but he does not indicate the species or genus to which he is referring. From fossils and dried specimens of *Conescharellina* the conclusion come to independently, is that there have been radicle processes, but in *Cupularia*, *Selenaria*, and *Lunulites* there is no indication of anything similar.

CLASSIFICATION.

We may now turn to he classification, as these investigations were made to find a natural one, and certainly we are brought up against a most difficult problem. Generally in *Cupularia*, *Selenaria*, and *Lunulites* there is a thick under surface, through which long tubes may pass, or there may be a series of chambers; further, the arrangement of the back as well as the front is radial, all of which seems to be quite different from anything known in other genera. In many cases in the Cheilostomata, such differences as whether the zoœcia are uni- or bilateral, or whether they are adnate or erect, are purely zoarial characters, of no or but slight value in classification, but the characters on the under surface, now dealt with, are not zoarial in the same sense, but are in connection with the zoœcia.

Looking at *Cupularia* and *Selenaria* with their similar opercula, similar lower surface, in most cases with central small zoœcia, often closed, with vibracula in both genera, there can be no hesitation in placing them in the same family; in *Lunulites*, the lower surface is radial and thick, long pores pass through it as in the last two genera, the opercula are similar, but there is a more solid calcareous frontal wall without perforations, though it clearly belongs to the same family. *Lunulites*, as generally understood, requires separating into several genera, as already indicated.

Conescharellina differs from *Cupularia* and *Selenaria* in many particulars, such as the shape of the separable operculum, the reversal of the position of the operculum, the semilunar slit, absence of radial under surface, although the zoœcia are placed radially; on the other hand, in the lower part there are a number of vertical chambers, which seem comparable with the horizontal ones of *Cupularia canariensis*, and it would be strange that species not closely allied should develop into a conical form with small central zooecia, and should have a series of chambers below the zooecia. Put shortly, are there a number of Bryozoa from different families with quite different zooecial characters which have taken on the same way of growth and subbasal characters, or have related forms with similar growth gradually assumed more divergent characters?

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* "Australian Polyzoa," p. 347, 1887.

† Presidential Address, Brit. Assoc. Zool. Section, p. (9). 1908.

Batopora has small chambers at the lower part, which Reuss and Stoliczka call abortive cells, and these may be homologous with the chambers of *Cupularia canariensis* and *Conescharellina.*

Gregory[*] would place *Batopora* under *Conescharellina*, but *Batopora* has an oral aperture with a more or less straight lower edge, and a large widely open ovicell—in fact, in most characters it resembles *Holoporella*, showing no reversal of the position of the zooecia, also the zoaria are more globular than conical. I am not sure that I understand what Gregory meant about the aperture of *Conescharellina clithridiata*, Greg., which seems to be *Holoporella* or *Cellepora.*

Trochopora, d'Orb. has the whole of the base filled in by a calcareous growth through which pass very long pore tubes (Pl. **30**. fig. 17). This character may not be universal and is discussed on page 418. The base has radial divisions just like those of *Lunulites*, *Cupularia*, &c., and in making sections these radial divisions are seen at every stage of the preparation (Pl. **29**. fig. 18). A specimen of *Selenaria nitida*[†], Maplestone, in the British Museum, from 22 miles E. of Port Jackson, has the cone entirely filled in with a solid calcareous mass, and in some cases shows radiating lines at the base just as in *Trochopora*. Canu & Bassler[‡] place *Trochopora* and *Otionella*, Can. & Bassl. under Membraporina[§], which belongs to Malacostega, but *Lunularia* they place with Opesiulidæ, that is Coilostega. If there were sufficient reason for this it would indicate that the new classification has some weak points, but I fail to find sufficient grounds for separating *Trochopora* from *Lunulites.*

My conclusions are, that of the forms with discoid or cupuliform growth there are two main divisions with one subgroup.

(1) Those with the operculum in the frontal membrane, a radial base, and usually no ovicell, including *Cupularia*, *Selenaria*, *Lunulites*, with *Selenariopsis*, Maplestone, *Trochopora*, d'Orb., *Otionella*, Can. & Bassl., *Heteractis*, Can. & Bassl.

(2) Those with usually a fairly large operculum fitting into the Lepralioid or Holoporellidan oral aperture; with a large ovicell widely open in front, as

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[*] "Brit. Paleog. Bry.," Trans. Zool. Soc. London, vol. xiii. pt. 6, p. 251 (1893).

[†] "Results of Deep Sea Investigations," Records of the Australian Museum, vol. vii. p. 271, pl. 77, fig. 8 (1909).

[‡] "Tert. Cheil. Bry.," U.S. Nat. Mus. Bull. 96, p. 10 (1917).

[§] Levinsen, "Morph. Cheil. Bry." p. 144. 1909.

in *Mamillopora*[*], *Sphæropora*, Haswell[†], *Kionidella*, Kosch., as well as *Batopora* and *Stichoporina*[‡], Stol. (*non* Kosch.) with smaller oral apertures. At the base the zoaria may be radial, or there may be a growth of zoœcia over the radiate zoœcia[§].

(3) As a subgroup, those with a small, nearly oval oral aperture, with a separable operculum, having muscular dots fairly near together. The zoœcia are directed to the apex, there are semilunar slits and a small raised globular ovicell, the avicularia are adventitious, whereas in *Cupularia* they are vicarious. Only *Conescharellina* is known in this subgroup.

The first division, if only the zoœcial characters were considered, would come under the Membraniporidæ of Levinsen[||], which is a very large family, or rather a casual ward for the homeless.

Canu[¶] places *Lunulites* under Onychocellidæ, but only a part have "onychocellaires," while some have vibracula, and others have avicularia, as proved by the symmetrical avicularian chambers; *Cupularia* he places under the Opesiulidæ, in which family he puts *Micropora*, as he recognized in the fossils, what most others had not appreciated, that the frontal pores, where they exist, are opesiules. The muscles passing through these pores have now been seen in my stained preparations.

Besides the genera mentioned, the question of the relationship of the following must be considered :—

1846. *Stichopora*, Hagenow.

1847. *Prattia*, d'Archiac, Mém. Soc. Géol. de la France, vol. iii. p. 407.

1851. *Discoporella*, d'Orb., is *Cupularia*.

1851. *Discoflustrella*, d'Orb., is *Cupularia*.

1851. *Discoflustrellaria*, d'Orb., Marsson says only worn *Lunulites*.

1851. *Cymbalopora*, Hag. This is much like *Conescharellina*. The underside has been mistaken for the upper side.

1863. *Discoescharites*, Roemer, Nord. deutsch. Tert. Poly. p. 21, is *Lunulites*.

1864. *Bicupularia*, Reuss, Sitzb. Akad. math.-naturwiss. vol. l. p. 9, pl. 3. fig. 2 (1864).

1882. *Ascosia*, Jullien, must be placed under *Mamillopora*.

1887. *Bipora*, Whitelegge, is *Conescharellina*.

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[*] See Neviaui, "Nuova specie fossile di Stichoporina," Riv. Ital. di Paleont. pp. 1–4. 1895.

[†] Proc. Linn. Soc. N.S. Wales, vol. v. p. 42, pl. 2. figs. 5, 6 (1880).

[‡] Stoliczka, "Olig. Bry. von Latdorf," Sitz. Akad. der Wissensch. Wien, vol. xlv. p. 92.

[§] This group is dealt with more fully in Waters, "*Batopora* and its Allies,' Ann. Mag. Nat. Hist. ser. 9, vol. iii. 1919.

[||] "Morph. Cheil. Bry." p. 143.

[¶] "Bry. foss. de l'Argentine," Anal. del Museo Nacional de Buenos Aires, vol. xvii. p. 275 (1908).

1893. *Biselenaria*, Gregory, nom. nov.=*Diloptaxis*,* Reuss (a name previously employed elsewhere). From Reuss's figure this looks like *Cupularia* with the frontal growth continued on the under side of the zoarium, meeting in the middle. *Sphæropora fossa*, Haswell, in the same way, grows from the upper side over to the under side (see "Batopora," p. 80).

1897. *Ennalipora*, Gabb & Horn. It is put by Yves Delage (with a ?) in the Selenarina, but this is clearly a slip.

1913. *Selenariopsis*, Maplestone.

Species of these groups have been dealt with in a large number of works, but special reference is made to structure or relationship in the following :—

Busk, Brit. Mus. Catal. pt. 2, p. 97. 1854. †(B.M. Cat.)

Busk, Fossil Polyzoa of the Crag, p. 78. 1859. †(Crag.)

Stoliczka, "Oligoc. Bry. von Latdorf," Sitz. Ak. der Wissensch. Wien, vol. xlv. p. 71. 1862.

Tenison Woods, "On some Recent and Fossil Species of Australian Selenariadæ," Trans. Phil. Soc. Adelaide, vol. iii. p. 1. 1880. †(Selenariadæ.)

Waters, "Bryozoa from N. S. Wales," Ann. Mag. Nat. Hist. ser. 5, vol. xx. pp. 199–202. 1887. †(N. S. Wales.)

Whitelegge, "Notes on some Australian Polyzoa," Proc. Linn. Soc. N. S. Wales, vol. ii. pp. 337–347. 1887. †(Austr. Poly.)

Maplestone, "Notes on the Victorian fossil Selenariidæ," Proc. Roy. Soc. Vict. N.S. vol. xvi. p. 207. 1904. †(Vict. Selenar.)

Maplestone, "On the Growth and Habit of Biporæ," Proc. Roy. Soc. Vict N.S. vol. xxiii. 1910. †(Biporæ.)

Maplestone, "The Exped. of H.M.C.S. 'Miner': Polyzoa," Rec. Austr. Mus. vol. vii. 1909.

Maplestone, Supplement, *op. cit.* vol. viii. 1910.

Waters, "*Batopora* (Bryozoa) and its Allies," Ann. Mag. Nat. Hist. ser. 9, vol. iii. p. 79. 1919. †(*Batopora.*)

The following also are referred to under the contractions † given :—

Canu, "Contributions à l'étude des Bry. foss. des Terrains du Sud-Ouest de la France," Bull. Soc. Géol. de France, various volumes. †(Bry. foss. France.)

Levinsen, Morph. and Syst. Studies on the Cheil. Bryozoa. 1909. †(Morph. Cheil.)

Manzoni, Bri. foss. del Mioc. d'Aust. ed d'Ungheria, Wien. Denks. xxxvii. 1877. †(Mioc. d'Aust.)

Manzoni, "Bri. plioc. Ital.," Sitz. Wissensch. Akad. Wien, lix.–lxxi. 1869–71. †(Bri. plioc. Ital.)

Norman, "Polyzoa of Madeira and neighbouring Islands," Journ. Linn. Soc., Zool. vol. xxx. †(Poly. Madeira.)

Waters, "Bryozoa from N. S. Wales," Ann. Mag. Nat. Hist. ser. 5, vol. xx. †(N. S. Wales.)

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* "Ueb. einige Bry. aus dem deutsch. Unterolig.," Sitz. Akad. Wiss. math.-nat. Cl. vol. lv. p. 231, pl. 2. figs. 5–7 (1867).

† Contractions used in the text.

CUPULARIA.

The name *Cupularia* was first suggested by Lamouroux for the fossil "*Lunulites urceolata*" Lamk., which Lamouroux subsequently figured for the first time, though neither from the description nor figure will it ever be possible to know what species was intended. D'Orbigny, accepting Lamouroux's suggestion, described the genus *Cupularia*, and Busk, apparently forgetting that d'Orbigny had done so, again introduced it. Canu * figures a species as *Lunulites urceolata*, Cuv. and says that this Paris basin species has been known for a century by geologists as *L. urceolata*, and so long as it is not considered as the species of Lamouroux, this seems to cause least difficulty, though Cuvier gave no description, but then we must not call *L. urceolata*, Cuv., as figured by Canu, a synonym of *L. urceolata*, Lamk. and Lamx., which it certainly is not. Lamouroux considered his species to be the unfigured *L. urceolata*, Lamk., and his description is verbally copied from Lamarck, to whom Lamouroux submitted much of his material.

Dr. Alice Robertson describes † *Cupularia* under incrusting Cheilostomata, and says "touching the substratum only on the rim of the colony." It is certainly incrusting in its earliest stages, but there is never an attachment confined to the rim. Nearly all forms of Bryozoa are incrusting in the earliest zooecia, but beyond this, *Cupularia* is not so in the sense in which it has been used for many Cheilostomata.

Cupularia is represented at present by a few species from temperate and tropical regions, and was abundant in the European tertiaries, with some in the cretaceous formation.

CUPULARIA CANARIENSIS, *Busk.* (Pl. **29**. figs. 1–5; Pl. **30**. figs. 11, 12, 21, 22, 25.)

Cupularia canariensis, Busk, Q. Journ. Micr. Sc. vol. vii. p. 66, pl. 23. figs. 6–9 (1859); "Crag," p. 87, pl. 13. fig. 2 (1859); de Angelis, "Anthoz. y Brioz. plioc. de Cataluna," R. Acad. de Cien. y Artes de Barcelona, p. 33, pl. B. figs. 6–9 (1900); Waters "N. S. Wales," p. 201 (1887); Waters, Zool. Chall. Exp. Suppl. vol. xxxi. p. 36, pl. 3. fig. 2 (1889); Q. Journ. Geol. Soc. vol. xli. p. 308 (1885); Robertson, "Inc. Cheil. Bry.," Univ. California Pub. Zool. vol. iv. p. 314, pl. 24. figs. 90, 91 (1908); Manzoni, "Bri. Plioc. Ital." pt. i. p. 10, pl. 2. fig. 17 (1869); "Plioc. sup. de Rhodes," Mém. Soc. Géol. de France, ser. 3, vol. i. p. 67 (1887); Seguenza, "Formaz. Terz. Reggio;" p. 371 (1879); Pergens, "Plioc. Bry. von Rhodos," Ann. k.k. nat. hist. Hofmus. vol. ii. p. 31 (1887); Neviani, "Cont. alla. Conosc. dei Bri. foss. Italiani," Bull. Soc. Géol. Ital. vol. x. p. 130 (1891); "Bri. foss. della Farnesina," Pal. Ital. vol. i. p. 101 (1895); "Bri. Neoz. di alcuni Loc. d'Italia," Bull. Soc. Rom. per gli Stud. Zool. vol. iv. p. 238 (14), p. 243 (1895); *op. cit.* vol. v. p. 121 (1896);

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* "Bry. des Terrains Tert. des Environs de Paris," Ann. de Paléont. vol. ii. p. 26, pl. 4. figs. 4–8 (1907).

† "Incrust. Cheil. Bry.," Univ. California Pub. Zool. vol. iv. p. 314, pl. 24. figs. 90, 91 (1908).

op. cit. vol. vii. p. 38 (5) (1898); Bri. Neog. della Calabrie, p. 168 (1900); Bri. Terz. ed Postterz. p. 362 (1900); "Bri. foss. di Carrabare," Bull. Soc. Géol. Ital. vol. xxiii. p. 552 (1905); Canu, Bry. foss. de l'Argentine," Ann. del Mus. Nac. de Buenos Aires, vol. xvii. p. 275. pl. 5. figs. 8-10 (1908); "Bry. foss. France," vol. xiii. pp. 124, 128 (1913); *op. cit.* ser. 4. vol. xvi. p. 137, pl. 3. figs. 4, 5, 6 (1917).

Membranipora canariensis, Smitt, Floridan Bry. pt. 2, p. 10, figs. 69–71 (1873).

Cupularia guineensis, Busk, B. M. Cat. pt. 2, p. 98, pl. 114 (1854); Zool. Chall. Exped. vol. x. p. 206, pl. 14. fig. 6 (1884); Norman, "Poly. Madeira," p. 289, pl. 37. figs. 2–6 (1909); Osburn "Bry. of the Tortugas Isl.," Pub. Carnegie Inst. 182, p. 194 (1914).

Lunulites canariensis, Manzoni, "Mioc. d'Aust." p. 72 (24), pl. 17. fig. 56 (1877).

Cupularia canariensis, as shown by stained sections, has at the base a series of parallel chambers (Pl. **29**. figs. 1, 2, 4) filled with granular substance, and with a connection from each chamber to its neighbours, through rosette-plates (see page 400). These chambers must surely be homologous with those of *Conescharellina*, as seen in *C. philippinensis, angulopora*, etc., even though the shape is somewhat different. In whole stained preparations of *C. canariensis* these chambers can be seen at the base forming squares or rectangles (Pl. **29**. fig. 5), yet in many cases the calcareous zoarium shows no sign of these squares, but only the radial lateral ridges meeting in the centre of the lower wall.

Careful examination, however, often shows the cross lines in some places, where only the more distinct radial lines are seen at first, and in some fossil forms the squares can clearly be distinguished, so that this is a character which must be dealt with cautiously.

No ovicells are known in *Cupularia*, but there are ova and large embryos shown in sections, from which it is clear that they emerge directly without passing into any external ovicell. In *C. canariensis* there are 14 tentacles, the same as in *C. Johnsoni.*

I have on several occasions maintained that *C. canariensis* and *C. guineensis* are synonyms, and Norman[*], agreeing with me in their identity, wishes to take Busk's earlier name of *guineensis*; but Canu, considering that *canariensis* has been universally used for half a century, and that for both these the author is the same, considers we should retain the name *canariensis*. Canu also thinks that the figure of *canariensis* was good, whereas that of *guineensis* was bad Having several times compared the British Museum specimens, it does not seem that we must speak of a bad figure, though in the specimens there may be in parts the structure as figured in *canariensis* as well as that of *guineensis*, and I agree with Canu in thinking we should retain the name *canariensis*, which has often been well described. Should other characters be found in *guineensis*, it will be open to re-consider the name.

Loc. Madeira; Canaries, 80–250 met. (*Calvet*); Florida (*Smitt*); Tortugas (*Osburn*); Cape Blanc (*Calvet*); Liberia; Philippine Is.; New Guinea;

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[*] Linn. Soc. Journ., Zool. vol. xxx. p. 289 (1909).

off Cape York, Australia; S. Pedro, 4 fath., and S. Catalina, California (*Rob.*); Oran (Algiers).

Fossil. Miocene: Austria and Hungary (*Manzoni*); Pliocene: Crag, Italy, Spain, Rhodes, Monte Mario, Rome; Pleistocene: California (*Rob.*); Quaternary: Italy; Tertiary: Bahia-Blanca, Argentine (*Canu*); Aldinga, Australia.

CUPULARIA LOWEI, *Busk.* (Pl. **30.** figs. 1–6, 26–29.)

Cupularia Lowei, Busk, B. M. Cat. p. 99, pl. 116. figs. 1–6 (1854); Norman, "Poly. Madeira," p. 290, pl. 37. figs. 7-12 (1909); Osburn, Bry. of the Tortugas Islands, Florida, p. 194 (1914).

Canon Norman kindly gave me a few spirit specimens, from Madeira, and of one I have prepared a most interesting whole stained decalcified preparation.

Looked at with the frontal membrane in focus, a number of small bundles of muscles (Pl. **30.** fig. 1) are seen which pass from the membrane through the frontal pores; then focussing lower down, as if the membrane had been removed, we see what must perhaps be called a semicircular opesium through which the polypide protrudes (fig. 2). The zooecia are connected by means of tubes in which there are septa or rosette-plates, where the neighbouring tubes join. The zooecial chambers are seen as quite separate sacs.

Looking at the zoarium from below, the zooecial chambers are separated by a considerable space, and to about the median line of the zooecial chamber there is a row of muscles which pass from the lower surface of the zooecial chamber to the lower surface (fig. 3) of the zoarium.

The muscle threads are usually single, though occasionally two or three occur together, and there are here and there similar muscles to other parts of the zooecial chamber. This hydrostatic system is different from anything yet recorded, and having in the lower part of the zoarium this muscular system and no basal chamber as in *C. canariensis*, Busk, it seems questionable whether they can remain in the same genus.

The calcareous dorsal surface, especially if rubbed down a little, shows short grooves, with frequently a pore at the end (Pl. **30.** fig. 4). These of course indicate where the row of bundles of muscle occur. The peripheral zooecia on the dorsal surface have small granulations, but the older parts have elongate slight protuberances.

The dorsal pore and grooves occur very distinctly in *Cupularia denticulata* fossil from Veletri, near Lorenzano, on the hills near Pisa, in my collection, and less distinctly on fossils from San Gemignano, near Siena, as well as from the Antwerp Crag (all collected by me). The same structure evidently occurs also in *C. Oweni*, Busk of the B.M. Cat., but this may be *umbellata*, and it may also be seen in *C. denticulata* of the Crag.

This species is much like *C. umbellata*, Defr., but the lobed or irregular growth of *C. Lowei*, as described by Busk and Norman, has not been mentioned in *umbellata*, though it occurs in "*Cupularia deformis*" Busk, MSS. in the British Museum, which however is closely allied to *C. denticulata*, with the denticles very wide and solid. The zoaria grow in irregular shapes, often lobed just like *C. Lowei*; and Reuss in his manuscript afterwards published by Manzoni * speaks of the growth of *C. Haidingeri*, Rss., being excentric, and from the figures it has the groove mentioned as occurring in *C. Lowei*. The "*deformis*" occurs from the Porcupine Expedition, 45 fath. (B.M.); Tangier Bay, 35 fath. (B.M.); Ras el Amourh, 45 fath. (B.M.); Cape Sagras (B.M.), Portugal; and in my collection from Mer el Kebir, Oran, 50 metres; I propose to place it under *denticulata*.

The polypide of *C. Lowei* is about double the size of that of *C. canariensis*. The frontal membrane has no trabeculæ comparable with that of *Selenaria maculata*, but there is a minute chitinous curve from the base of the oral aperture to the boundary of the zoœcium (Pl. **30**. fig. 1). We thus know *Cupularia* with regular, and others with irregular zoaria of the *Lowei* form, having large frontal pores; also the same zoarial forms with denticulate lamina.

Loc. Madeira (*Busk*), common in 50–70 fath. (*Norman*); Tortugas Islands, 12–22 fath. (*Osburn*); North Carolina (*Verrill & Osburn*); Oran.

CUPULARIA JOHNSONI, *Busk*. (Pl. **29**. fig. 17; Pl. **30**. figs. 23, 30, 31.)

Cupularia Johnsoni, Busk, Q. Journ. Micr. Sci. vol. vii. p. 67, pl. 23. figs. 1–5 (1859); Norman, "Poly. Madeira," p. 290, pl. 38. figs. 1–6 (1909); Canu, "Bry. foss. France," vol. xvi. p. 139 (1917).

Cupularia Reussiana, Manzoni, "Bri. plioc. Ital." p. (11), pl. 2. fig. 19 (1869); "Bry. plioc. sup. de l'Ile de Rhodes," Mém. Soc. Géol. de la France, ser. 3, vol i. p. 67 (1877); Waters, "Bry. from the Plioc. of Bruccoli," Trans. Manchester Geol. Soc. vol. xiv. p. 480 (1878); Seguenza, "Formaz. terz." pp. 131, 208 (1879); Neviani, "Bri. Neoz. di alcune loc. in Italia," Bull. Soc. Rom. vol. iv. p. (7), 115 (1895): *op. cit.* vol. iv. p. 243 (19) (1895); "Bri. Neog. della Calabrie," Pal. Ital. vol. vi. p. 169 (1900).

Discoflustrella doma, d'Orb. Pal. Fr. vol. v. p. 561 (1850–2).

Cupularia doma, Smitt, "Floridan Bry." pt. 2, p. 15, pl. 3. figs. 81, 84 (1878).

The Madeira specimens, though in spirit, had evidently been dead some time before preservation, and externally had grains of sand adhering to the membranes, while internally diatoms were numerous, so that satisfactory preparations were impossible.

The large cells lining the zoœcial and other walls are very marked, and the embryos (about 0·5 mm. long) nearly fill the zoœcial chambers. They are about the same size as in *C. canariensis.* The under surface of the Oran specimens are spinous (Pl. 29. fig. 17), but in a fossil from Rhodes the under surface is uneven, rather mamillate than spinous, and a fossil from Monte Mario, near Rome, is almost plain underneath.

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* "Mioc. d'Aust." p. 71, pl. 16. fig. 54 (1877).

This was, no doubt, first met with by d'Orbigny, who called it *Discoflustra doma,* but it was not figured, and the description was insufficient for recognition, though now having specimens from the same locality as d'Orbigny, with the "dessous très rugeux comme epineux," we may feel practically certain as to the identity, though as Busk first gave it a recognisable description it must be called *Johnsoni.*

More than one mistake has been caused through d'Orbigny creating the genus *Discoflustrellaria,* with the species *doma* (probably *Lunulites*), and also *Discoflustrella* with the species *doma.*

Loc. Madeira; Mediterranean; Oran, Algiers (*Waters & Canu*), 152 fath.; Benzert Road, Tangier, and Ras el Amourh, 45 fath. (all Brit. Mus.).

Fossil. Castelarquato, Bruccoli, Rhodes (Pliocene); Ravagnex (*Nev.*), Amato (*Nev.*), Benestare (*Seg.*), Tortonian; Terreti (*Seg.*); Leognan, Gironde, France (Burdigalien) (*Canu*).

CUPULARIA UMBELLATA (*Defrance*).

Lunulites umbellata, Defrance, Dict. des Sc. Nat. vol. xxvii. p. 361 (1823).

Lunulites urceolata, Blainville, Man. d'Actin. ou de Zoophytologie, p. 449, pl. 72. fig. 1 (1834).

Discoporella umbellata, d'Orb. Pal. Fr. p. 478, pl. 717. figs. 1–5 (1850–2).

Discoporella Beradana, d'Orb. *loc. cit.* p. 474.

Lunulites Haidingeri, Reuss, Foss. Polyp. des Wien. Tert. p. 58, pl. 7. figs. 26, 27 (1847).

Cupularia Haidingeri, Manzoni, "Mioc. d'Aust." p. 71 (23), pl. 16. fig. 54 (1877); Canu, "Bry. foss. France," vol. xiii. pp. 124, 125, 128 (1913); p. 320 (1915); *op. cit.* vol. xvi. p. 138 (1917).

Cupularia umbellata, Manzoni, "Bri. Plioc. Ital." pt. 1, p. 26 (10), pl. 2. fig. 16 (1869); "Bri. del Plioc. Ant. di Castrocaro," p. 39, pl. 5. fig. 67 (1875); Smitt, "Floridan Bryozoa," p. 14, pl. 3. figs. 75–80 (at least 79, 80) (1873); ? Hincks, "Poly. and Hyd. of the Mergui Archipelago," Journ. Linn. Soc. vol. xxi. p. 125 (1887); Seguenza, "Terz. Reggio." pp. 131, 296, 371 (1879); Calvet, Expéd. Sc. du 'Travailleur' et du 'Talisman,' vol. viii. p. 393 (1907); Canu, "Bry. foss. de l'Argentine," Ann. del Mus. Nac. de Buenos Aires, vol. xvii. (ser. 3, vol. x.) p. 275, pl. 5. figs. 4, 5 (1908); "Bry. foss. France," ser. 4, vol. ix. p. 448 (1909); vol. xiii. p. 130 (1913); vol. xiv. p. 322; vol. xv. p. 392 (1916); vol. xvi. p. 137 (1917); Neviani, Boll. Soc. Rom. per gli Studi Zool. vol. iv. p. 243 (1895); * "Bri. foss. della Farnesina" (pars), Pal. Ital. vol. i. p. 101 (1895); Canu, "Bri. Helv. de l'Égypte," Mém. Inst. Égyptien, vol. vi. p. 205 (1912).

When the frontal calcareous wall is partly broken down there is resemblance to *C. denticulata,* which has sometimes caused confusion between the two, but specimens of fossil *umbellata* from the Pliocene of S. Gemignana, near Siena (one of which is flat and must have been at any rate 25 mm. in diameter, while another is more raised and is 8 mm. diameter), show that the proximal part of the oral aperture is a calcareous bar or wall, often directed upwards, while near each end there is a small ridge or tooth, and the frontal wall has a row of large pores near the border, with smaller ones in the central portion. A part of the zoarium, not quite at the centre of the large piece, has a thick wall over the front with few small pores and sometimes with no opercular aperture. This structure is the same as that of the central zooecia.

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* I am unable to accept all his synonyms.

Specimens I collected from the Antwerp Crag, and consider to be *denticulata*, have no calcareous wall up to the proximal end of the oral aperture, except in a few cases near the centre of the zoarium, where there are 4–5 very large pores and not a row round the border. The denticles are large and stout, whereas in the broken down *umbellata* mentioned they are much more numerous and smaller.

*C. umbellata**, as described, differs from *C. Lowei* in having regular zoaria instead of irregular and lobed-shaped ones, as well as in some zooecial characters. A new genus must probably be created for *C. Lowei*, *C. umbellata*, etc.

Loc. Florida (*Smitt*); Canaries (*Canu*); Cape Verde Islands, 1900 met. (*Calvet*); Mergui Archipelago (*Hincks*).

Fossil. Oligocene and Miocene: France; Miocene: Austria and Hungary; Pliocene: Crescentino, Bordighera, Siena (*A. W.*); Rhodes.* Burdigalian, Helvetian, Tortonian, Plaisancian, Astian, Sicilian, and Quaternary of Italy. Bahia-Blanca, Argentine (*Canu*).

SELENARIA CONCINNA, *Tenison Woods*. (Pl. **30**. figs. 7–10.)

Selenaria concinna, T. Woods, Trans. Phil. Soc. of Adelaide, vol. iii. p. 10, pl. 2. figs. 11 *a*–11 *c* (1880); Waters, "N. S. Wales," p. 201, pl. 5. fig. 11 (1887); MacGillivray, "Tert. Vict." p. 48, pl. 7. fig. 15 (1895).

At the distal end of the vibraculum there is an incomplete ring attached by a kind of stalk at one side of the vibraculum. This is seen in fig. 8, with the zoarium somewhat tilted so as to look into the opening. The base of the seta works upon this incomplete ring and the muscles pass through the ring. I † spoke of this ring in *S. concinna*, Busk as a tubular projection and also figured it.

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* Pergens in his "Bry. von Rhodos," p. 30, gives the synonyms of *umbellata*, and on the next page after "non" gives a list of species not to be placed under *umbellata*. Miss Jelly unfortunately seems to have overlooked the "non," and in her Catalogue makes Pergens responsible for placing five of these species under *umbellata*.

† "N. S. Wales," p. 201, pl. 5. fig. 11 (1887).

The primary zoœcium is surrounded by five secondary zoœcia, and there are three vibracula, so that we get eight chambers, which is the number of surrounding zoœcia in so many of the group, that it seems almost general. The earlier vibracula are much smaller than the later ones, which are also relatively much wider.

MacGillivray expresses some doubt as to whether the specimens which I described were the species of T. Woods, who described the avicularian chamber as having the edges studded with very fine teeth. I concluded that Woods' specimens had the front broken down, when instead of the pores described by me we have irregular teeth. It does not seem that there can be any doubt as to the recent and fossil forms being the same species.

The opesia are much larger than the operculum, except in the central zoœcia, where the operculum is the same size as the calcareous opening. In *Lunulites* the opening is similarly opesial.

Loc. Off Port Stephens, New South Wales, 25 fath.

Fossil. Muddy Creek, Gellibrand, and Lake Bullenmerri, Victoria (*MacG.*).

SELENARIA PUNCTATA, *Tenison Woods.* (Pl. 29. fig. 7.)

Selenaria punctata, T. Woods, Trans. Phil. Soc. Adelaide, vol. iii. p. 9, pl. 2. fig. 8 (1880 Waters, "N. S. Wales," p. 201 (1887); Maplestone, Proc. Roy. Soc. Victoria, N.S. vol. xvi. p. 208, and described again on p. 212, pl. 24. fig. 2 (1904).

S. fenestrata, Haswell, Proc. Linn. Soc. N.S.W. vol. v. p. 42 (1880).

My recent specimens from Port Stephens and from Princess Charlotte Bay, N.E. Australia, are a trifle larger than the measurements given by Maplestone, the zoœcia being 0·23 mm. wide and long. I * called a fossil from Muddy Creek *punctata*, though mentioning the size of the aperture as 0·21 mm., whereas in the recent form it is only about 0·09–0·14 mm. Later MacGillivray † placed the fossil as *T. punctata* and called attention to the large size of the zoœcia.

Maplestone ‡ would call the fossil *S. magnipunctata*, though it is an open question as to whether the mere difference in size between a tertiary fossil and recent forms is sufficient to necessitate a new species. However, in 1887 I was describing recent forms which are *S. punctata*, and therefore Maplestone has made a slip in placing these under the synonyms of *magnipunctata*. The *S. fenestrata*, Hasw., presented by the Australian Museum to the British Museum, is the *magnipunctata* of Maplestone.

Loc. Off Cape Three Points (*Woods*); Holborn Island (*Haswell*); Princess Charlotte Bay, Port Stephens, N.S.W.; Port Jackson.

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* Quart. Journ. Geol. Soc. vol. xxxix. p. 440 (1883).

† "Tert. Poly. Victoria," p. 47, pl. 7. figs. 8, 9 (1895).

‡ "Vict. foss. Selenar." p. 212, pl. 24. fig. 2 (1904).

SELENARIA MACULATA, *Busk*. (Pl. **29**. fig. 8 ; Pl. **30**. figs. 13–15.)

For synonyms see Miss Jelly's Catalogue and add: MacGillivray, Tert. Poly. Victoria," p. 47, pl. 7. figs. 5, 6, 7 (1895).

As mentioned in my Supp. Rep. Zool. Chall. p. 38, there are spreading round the oral aperture, and ending somewhat lower than the operculum, trabeculæ in the frontal membrane, reminding us of the trabeculæ described by Busk in *Cellaria*, and which also occur in *Onychocella angulosa*, Rss. Busk says that the trabeculæ "appear to lie beneath the common epitheca and not to form mere thickenings of it." Where I have examined them they seem to form part of the membrane. In *Onychocella angulosa* the ends are raised and thicker, and seem to be for the attachment of the muscles to the membrane. The different shapes of the trabeculæ seem to give useful characters wherever they occur. The vibracular setæ are spinous on the one side (fig. 13).

Loc. Holborn Island, Queensland ; Barnard Island, N.E. Australia, 10 fath.

Fossil. Muddy Creek, Bird Rock, Schnapper Point, Belmont, and Cape Bullenmerri (Victoria) ; River Murray Cliffs, S. Australia.

LUNULITES CUPULUS, *Busk*. (Pl. **30**. fig. 16.)

Lunulites cupulus, Busk, Voyage of the 'Rattlesnake,' p. 1, pl. 1. figs. 13, 14 (1852); B.M. Cat. p. 100, pl. 112. figs. 1–6 (1854).

Lunulites gibbosa, Busk, B.M. Cat. p. 100, pl. 111. figs. 1–6 (1854).

Judging from the chamber the appendage is apparently avicularian, that is to say it has movement in one direction only, but without seeing spirit specimens it is best not to speak too definitely. The mandible or seta is long and large, gradually diminishing to the apex (fig. 16), and near the apex a small branch grows from the side. The figure is taken from a preparation in the British Museum, made by Busk, and only labelled "hairs of *Lunulites*," but comparison with the type-specimen shows that it is certainly from *L. cupulus*, B.

This is clearly allied to *Lunulites repandus*[*], Maplestone, and *L. patelliformis*[†], Mapl. (non Marsson), but without examining specimens it is not advisable to say more. The fossil *L. patelliformis*, Marsson[‡] (non Mapl.) and *L. semilunaris*, Marss.[§], seem also to belong to this group.

Busk changed the name *Lunulites* to *Lunularia*, a change which has not seemed to me necessary, though it might have been better in the first instance. However, the modification did not make a new genus, so that under no circumstances could *Lunulites cupulus*, as proposed by Canu and Bassler, be the type of the genus, for being mentioned in the 'Challenger' Reports in the re-named genus, it does not replace the type, which is, whatever Lamouroux meant for his *L. radiata*, an abundant form under various names.

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[*] "Victorian Selenariidæ," vol. xvi. N.S. p. 216, pl. 25. fig. 7 (1904).

[†] "Vict. foss. Selenar." p. 215, pl. 25. fig. 6.

[‡] "Bry. Weiss. Schreibkreide des Insel Rügen," Pal. Abh. vol. iv. p. 79, pl. 7. fig. 11 (1887).

[§] *Loc. cit.* p. 78, pl. 7. fig. 10.

In all probability *L. cupulus* will have to be placed in a new genus, partly based on the long zoœcia and the stout seta with a simple base.

TROCHOPORA, *d'Orbigny*. (Pl. 29. fig. 18; Pl. 30. fig. 17.)

Although I have seen many specimens of *Trochopora*, the state of preservation has not allowed a satisfactory examination of the avicularian (?) chambers, nor are they shown clearly in published figures. The fossils readily break both along the radial and annular lines, and change of the shell has taken place so that the minute structure cannot be studied. Near the tubes passing through the calcareous base, and also near some of the annular lines, the calcareous matter has become chalky, showing in section white against the more transparent parts. In making horizontal sections the radial divisions, as in fig. 18, are seen in every part of the solid interior, that is to say, there is a succession of the same structure.

The interior of the cone is filled in with a solid calcareous mass in species described as *Trochopora*, but I have not been able to see that it should be separated from *Lunulites*, and finding that *L. conica*, as described and determined by Busk, from the Crag, is sometimes solid and sometimes hollow, as stated by Busk, has confirmed my opinion. Specimens 6722, 6723, 6724, British Museum, are filled in below and are solid, while 6718, from the Red Crag of Sutton, are hollow cones about the same size, with similar annular divisions and similarly worn.

In the British Museum there are also specimens named by various collectors *Lunulites conica*, many large like the Crag specimens; and in boxes from numerous European localities the solid and hollow forms occur together. There seems ample reason for considering that *Lunulites* and *Trochopora* cannot be separated generically, and further, though very difficult to understand, it does not seem that a specific distinction can be made between those that are solid and those that are hollow. Also we must see whether the large forms sometimes called *urceolata* and the small one, as figured by Michelin, are distinct. Further studies with freshly gathered material may help us.

A specimen of *Selenaria nitida*, Maplestone, in the British Museum has the under surface filled in just as in *Trochopora*; however, the vibracular chambers are very small and narrow, and at first they were overlooked, but a few are made out clearly. We thus get this structure in two quite distinct groups.

HELIODOMA IMPLICATA, *Calvet*.

Heliodoma implicata, Calvet, Bull. Mus. Hist. Nat. p. 157 (1906); Expéd. Sc. du 'Travailleur' et du 'Talisman,' vol. viii. p. 396, pl. 26. figs. 7, 10 (1907).

In the British Museum there are some specimens, 1253, to which Busk had given the manuscript name *Cupularia minima*. They grow on grains of sand, shell, or portion of stalk, and the single spiral form of growth can be followed, though it is not so marked as figured by Calvet, and does not end abruptly. The interesting point is that the auricular process is always on the same side; now in the Cupularidæ generally there is a co-relation between the position of the polypide and of the vibraculum, so that a row having the polypide turned to the right (as shown by the cæcum being to the right) will have the auricular process also on the right. In other Cupularidæ there may be one, two or more rows with all turned to one side; when a change takes place, the position of both the polypide and the vibraculum alters together.

Although in the small specimens only a single spiral is visible I should hesitate to make a specific separation, though further material may make this necessary. The spiral growth is most interesting and perhaps nothing quite similar is known in other Bryozoa.

Loc. Cape Verde Islands, 1900 met.; Canaries, 3700 met. (*Calvet*); Ægean Sea, 130 fath., collected by Spratt.

CONESCHARELLINA CANCELLATA (*Busk*). (Pl. **29**. fig. 22.)

Lunulites cancellata, Busk (pars), B.M. Cat. p. 101, pl. 113. fig. 5 (non 6) (1854); Waters, "Bry. from Bairnsdale," Q. Journ. Geol. Soc. vol. xxxviii. p. 512, pl. 22. figs. 10, 11 (1882).

Bipora cancellata, Whitelegge, "Austr. Poly." p. 340 (1887); MacGillivray, "Tert. Victoria," p. 89, pl. 12. fig. 1 (1895).

Conescharellina cancellata, Waters, "Bry. N. S. Wales," p. 200, pl. 4. fig. 24; pl. 6. figs. 13, 18 (1887).

In the British Museum specimens thus named by Busk belong to three or four species. Specimens from Busk's own collection so named are *C. angustata*, d'Orb., of which species I figure a specimen (Pl. **30**. fig. 18) from China, sent to me thus named by Jullien. The specimen, pl. 113. fig. 6 (as *cancellata*) in the British Museum Catalogue, has round avicularia as in *C. philippinensis* without any notch in the outer zoœcia, but the minute pore by the proximal end is just visible. The cone is somewhat higher than in *C. philippinensis* in my collection, though no doubt it is that species, as are also the other two small specimens. The larger specimen on the same slide has the base about twice the diameter of *C. philippinensis.* It has small round or oval avicularia, but the preservation is not very satisfactory.

The under surface of *C. cancellata* has some chambers with one large pore in the centre of the basal wall, sometimes surrounded by small pores, as in *C. angulopora*, Haswell (Pl. 29. fig. 21) and *C. flabellaris*, Lev., while generally there is the large opening of the chamber and smaller openings round it as in Pl. 29. fig. 22. My specimen is from Port Stephens, New South Wales, and, although the front surface is not very well preserved, I think it is the same as Busk's large specimen, for which the name can be retained. My specimen is 4 mm. at the base.

The mistake made, when the type was described, by Busk led me astray when my New South Wales and other specimens were compared in the British Museum, in consequence the specimens then called *cancellata* by me are seen to be *philippinensis.*

Loc. Philippine Islands (*Busk*); Port Stephens, N.S. Wales (*A. W. W. coll.*).

Fossil. Bairnsdale, Gippsland.

CONESCHARELLINA PHILIPPINENSIS (*Busk*). (Pl. 29. figs. 11, 12, 13; Pl. 30. fig. 24.)

Lunulites philippinensis, Busk, B.M. Cat. pt. ii. p. 101, pl. 113. figs. 1, 2, 3 (1854).

Bipora philippinensis, Whitelegge, "Austr. Polyzoa," vol ii. p. 341 (1887); MacGillivray, "Tert. Poly. of Vict." p. 89, pl. 12. fig. 2 (1895); Maplestone, "Biporæ," p. 3 (1910); Levinsen, Morph. Cheil. Bry. p. 300, pl. 24. fig. 1 (1909).

Conescharellina cancellata, Waters (pars), "N.S. Wales," p. 200. pl. 4. fig. 24; pl. 6. figs. 13, 18 (1887).

The comparison of Busk's type-specimens led me astray, on a previous occasion, as he had placed more than one species under *L. cancellata*, one of these was *C. philippinensis*, but more preparations and more material of the Selenariadæ has enabled me to feel more certain of my position. Unfortunately of *philippinensis* I have only dry specimens, and of all the Selenariadæ have only seen the three spirit specimens mentioned. I have a considerable number of *philippinensis* ranging from very young specimens, from under 1 mm. in diameter, up to mature forms nearly 3 mm. The zoarium is usually rather watch-glass shape, that is convex above and concave below, but it may be flat below; in either case there are a number of small raised avicularia with a semicircular mandible in the middle of the wall of the avicularian chamber.

The oral aperture is oval with a sinus in the part nearest to the periphery of zoarium, there is a distinct notch in the secondary aperture of the outer zooecia, and a minute pore by the other end of the oral aperture. Numerous round avicularia occur on the front of the zoarium, similar to those on the under surface, and typically there is one on each side of the zoœcium, and one below the aperture.

On the under side of the zoarium there are a number of chambers (Pl. **29.** fig. 11), the youngest ones being avicularian. These chambers, apparently, must be compared with those of *Cupularia canariensis*, and are found in *Conescharellina philippinensis*, *C. angulopora*, *C. cancellata*, *C. flabellaris*, *C. conica*. Whitelegge speaks (*loc cit.* p. 431) of the zoœcia taking their origin from the cancellated structure, but it is now clear that the zoœcia grow first, and from them the cancellated structure.

The semilunar slit to which Whitelegge called attention, and which Maplestone has also studied, occurs in this species. These semilunar slits have not a definite position in relation to the zoœcia, being most abundant near the apex of the zoarium, and sometimes several are found in the same circle somewhere near the apex, others in a circle half-way between this and the periphery, thus there is considerable irregularity and variation.

In some Conescharellinæ there seem to have been radicles from near the apex, where there is a considerable calcareous cap with pores (Pl. **29.** fig. 16), but this is not the case in *C. philippinensis*, in which there is no such calcareous growth, but on p. 405 it is suggested that radicles grew from the semilunar slits, and I expect with living or spirit specimens we shall see confirmation of deductions made from dried specimens. However, I have found no indications suggesting radicles, except in *Conescharellina*, and perhaps *Batopora*.

In the young *philippinensis* the under surface is flat or slightly concave, whereas in older ones the under surface is concave. The younger zoœcia are very much smaller than the older ones, and the secondary apertures are also smaller. A figure (Pl. **30.** fig. 24) of a very young zoarium is added, as it shows the small size of the zoœcia, and also the typical position of the avicularia at each side of the zoœcia, which is not so easily seen in more mature forms, as the avicularia are then more irregularly placed.

The raised and globular ovicell, described by Whitelegge and figured by Maplestone, is directed towards the apex. A specimen with ovicells was given to me by Maplestone, but altogether only very few have been seen.

Loc. Philippine Islands (*Busk*) ; Katow, New Guinea, 7 fath. ; Darnley Island, Torres Straits, 10–30 fath. ; Princess Charlotte Bay, N.E. Australia, 13 fath. ; Port Stephens "from weeds on sandy bottom," dredged by Brazier ; Moreton Bay, N.E. Australia (*Whitelegge* in lit.) ; Port Jackson.

Fossil. Curdies Creek, S.W. Australia ; Schnapper Point (*MacG.*).

CONESCHARELLINA FLABELLARIS, *Levinsen.*

Conescharellina flabellaris, Levinsen, "Morph. Cheil. Bry." p. 312 (1909).
Conescharellina elegans, Waters, "N. S. Wales," p. 200, pl. 5. figs. 13–17 (1887).
Bipora (?) ***elegans***, Whitelegge, "Austr. Polyzoa," vol. ii. p. 346 (1887).

In my "Notes on some Recent Bryozoa in d'Orbigny's Collection," *

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* Ann. Mag. Nat. Hist. ser. 7, vol. xv. p. 3, pl. i. fig. 5 (1905).

I said that the examination of d'Orbigny's specimens showed that his *Flabellopora elegans* is not what I described as *Conescharellina elegans*, and since then Levinsen has suggested the specific name *flabellaris* for the latter, and I have adopted it.

One specimen (fig. 17, *loc. cit.*) which I figured is quite bilaminate, while others (like figs. 15, 16, *l. c.*) are much wider, so that the section of one specimen is very much like that of *angulopora* or of *conica* (Pl. **29.** fig. 16). The under surface has chambers with a large round pore in the centre and five or six small pores surrounding it, just as in *C. angulopora*, T. Woods (Pl. **29.** fig. 21). The avicularia on the upper surface are small and round, whereas in *C. angulopora* and *C. conica* they are large and triangular.

The semilunar slit occurs in various places, but perhaps most often in the region of the apex and the border. The slit is materially wider than the aperture of the ordinary zoœcia, which, as I have suggested before, seems to indicate that the slit could not be for the formation of a zoœcium or zoœcial aperture. In other species there are typically a pair of avicularia by the slit, but there is no rule in this species.

Loc. Port Stephens, N. S. Wales, 7–8 fath.; Port Jackson (*Whitelegge & Lev.*)

CONESCHARELLINA ANGULOPORA (*Tenison Woods*). (Pl. **29.** figs. 6, 19, 21; Pl. **30.** fig. 19.)

Lunulites angulopora, Woods, "Austr. Selenariadæ," vol. iii. p. 7, pl. 1. figs. 3*a*–3*c* (1880); Whitelegge, "Austr. Polyzoa," vol. ii. p. 343 (1887).

Lunulites incisa, Hincks, Ann. & Mag. Nat. Hist. ser. 5, vol. viii. p. 127, pl. 4. figs. 1–3.

Conescharellina angulopora, Levinsen, "Morph. Cheil." p. 311, pl. 23. figs. 7 *a*–7 *f* (1909).

? *Conescharellina depressa*, Haswell, "Poly. from Queensland Coast," Proc. Linn. Soc. N. S. Wales," vol. v. p. 41, pl. 3. fig. 4 (1880).

There are two very similar species from Australia, but the present one has the larger zoaria with the base of the cone more spread out; the zoœcia and avicularia are also larger, the peristomes at the sides of the oral aperture are more raised, as is also the avicularian chamber and beak. However, the most important character is furnished by the under surface, as the basal wall of the cancelli has a large central perforation with smaller ones round it (fig. 21), as a rule without avicularia, though I saw one case in which there was an avicularian bar to the larger perforation. These perforated walls of the cancelli are mentioned by Tenison Woods in his *angulopora*, and by Haswell for his *Conescharellina depressa*, and although Haswell's figures do not correspond closely with my specimens, there is the probability of both being the same species. The under surface of *C. flabellaris*, Lev., is quite similar. The semilunar slit is larger than in other species examined, being wider than the zoœcial aperture, which would seem to show that it is not for the formation of a zoœcial aperture; the slit may occur either in the row of the zoœcia or of the avicularia, and often the disk of the semilunar slit has disappeared leaving only a semicircular opening. There is a pore-tube in the wall, at the proximal end of the oral aperture, and a similar tube occurs in *C. philippinensis*, Busk, *C. flabellaris*, Lev., *C. conica*, Hasw., and has been referred to by Levinsen (*loc. cit.* p. 309), and by Whitelegge (*loc. cit.* p. 339).

The dorsal surface of the smaller allied form (see *C. conica* p. 423) has moderate-sized pores with usually a few small triangular avicularia scattered about, though in some specimens none are found. A specimen from Port Stephens, which I think must be *C. cancellata*, Busk, has fairly large round openings at the base with smaller round openings near the larger ones, sometimes surrounding them, in other cases irregularly placed. The base of *C. philippinensis* has numerous small round avicularia, so that the basal surface of *Conescharellina* gives most useful characters. Woods' figure is very unsatisfactory and might represent either of two or three species; though from it together with the description we seem justified in using his specific name. McGillivray* gives this with a ? as fossil, but it really seems as if both his description and figure have got in the wrong places, at least I cannot understand them.

Loc. Port Stephens, N. S. Wales (*Woods*), and 25 fath. sandy mud bottom (sent by Brazier); Bass's Straits (*Hincks*).

CONESCHARELLINA CONICA, *Haswell* (non *Hantken*). (Pl. **29**. figs. 16, 20.)

Conescharellina conica, Haswell, Proc. Linn. Soc. N. S. Wales, vol. v. p. 42, pl. 3 figs. 7, 8 (1880).

Conescharellina incisa, Waters (pars), "N. S. Wales," p. 199, pl. 6. fig. 26 (1887).

In describing *C. angulopora*, Woods (p. 422) I have said that there were two very similar Australian species. This smaller one has, however, the axis of the cone relatively much longer, while the larger one has the base relatively much larger. The zoœcia and avicularia are somewhat smaller as is also the semilunar slit, but the most important difference is in the character of the base, for on the under surface of *conica* there are moderate-sized pores, with usually a few small triangular avicularia scattered about, though in some cases none have been found.

I have a specimen of undoubted *C. conica*, Haswell, from Holborn Island, sent to me by Haswell, and which no doubt was determined by him, though, as it is a long time since it was received, more cannot be stated.

At one time it seemed that the name *conica* could not be retained, as it has been used in several closely allied genera, but as we are getting more definite ideas about the genera, there is not as much force in the objection as there was then.

Loc. Holborn Island (*Haswell*); N.E. coast of Australia, 23 fath. (sent by Brazier).

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* "Tert. Victoria," p. 46, pl. 8. fig. 1 (1895).

CONESCHARELLINA EOCÆNA, *Neviani.*

Conescharellina eocæna, Neviani, "Bri. Eoc. del Calcare nummulitico di Mosciano presso Firenze," Bol. Soc. Geol. Ital. vol. xiv. p. 122 (6) fig. 5 (1895); Waters, "Batopora," p. 85, pl. 6. figs. 8, 12 (1919).

Batopora conica, Seguenza, "Form. Terz." p. 42, pl. 4. fig. 10 (1879).

Batopora conica, Hantken (*non* Haswell).

This at first was taken for *Batopora*, but the shape of the cone is the same as in various Conescharellinæ, while sections show its relationship, as the interior of the cone is filled in by chambers longer in the direction of a line from the apex to the base (fig. 8, *loc. cit.*). The zoœcia are in irregular longitudinal lines, and are hexagonal or round, with large pores between the neighbouring zoœcia. The visible aperture, which is probably only the secondary aperture, is round or oval. Near the apex of the zoarium there are only small openings with a larger one at the apex, though this is smaller than the pits of *Sphæropora* and *Batopora*. On other *Conescharellina* I have often seen small openings in the secondary growth over the apex, but have never found a central pit. The base of the zoarium shows large pores much like those of *C. conica*, Haswell (Pl. **29**. fig. 20). The ovicell is wide, slightly raised, and only occurs near the base of the zoarium.

This seems to be the only species of *Conescharellina* known from the Italian tertiaries, and in some respects it varies from most Conescharellinæ.

Hantken has frequently mentioned *Batopora conica*, Hantk., but attempts made by various people to find where he has described it have failed, and I have in vain looked through most of his papers. Finding specimens presented by Hantken in the British Museum (B. 3724), is therefore most interesting. It is conical, about 5 mm. high, there is considerable swelling at the apex, and one of these shows a hollow surrounded by very small pores, with larger ones over the rest of the swelling. The zoœcia have a nearly round aperture and smaller openings round them. One specimen is cut longitudinally through the middle, showing the cancellate structure, just as in my figure 8, *loc. cit.* The preparation referred to was no doubt made by Hantken.

Loc. Fossil: Mosciano near Florence (*Nev.*); Spiassi, Monte Baldo, N. Italy; between Grotte and Sarego near Lonigo, N. Italy (*A. W.*); Tongrian: Antonimina, Calabria (*Seg*); Buda Pesth, Lower Clay, Szaboi beds (*Hantken*); also from Schönthal, Festungsberg, Klein, Schwabenberg, and Üröm (*Hantken*).

EXPLANATION OF THE PLATES.

PLATE 29.

Fig. 1. *Cupularia canariensis*, Busk, × 25. Stained transverse section showing the shallow central zoœcia (*c.z.*), which have grown upon some substance removed in decalcification, and the large zoœcia (*l.z.*), as well as the vibracular chamber (*v.*) shown near the periphery of the zoarium. The lower part of the zoarium is formed by a series of parallel chambers filled with granular contents and connected by rosette-plates.

2. Do. do. × 200. Lower part of chambers with contents. A and B are connected by a rosette-plate, whereas B and C are close together but not connected at this level. Transverse wall (*t.w.*). Lateral wall of the series (*l.w.*).

3. Do. do. × 250. Transverse section showing contents of the chamber and the large cells.

4. Do. do. × 25. Transverse calcareous section showing chambers.

5. Do. do. × 25. Decalcified base of the zoarium, with muscles of one vibraculum.

6. *Conescharellina angulopora*, T. Woods, × 25. Calcareous section, showing the chambers at the base of the cone. *a* × 3. From Port Stephens, N. S. Wales.

7. *Selenaria punctata*, T. Woods, × 12. Showing a piece from which the central supporting flake has disappeared. From Port Stephens, N. S. Wales.

8 *Selenaria maculata*, Busk, × 12. Showing a piece of shell on which the colony has commenced to grow. It will be noticed that the early central zoœcia are very small. From Holborn Island.

9. *Selenaria petaloides*, d'Orb., × 6. Starting on shell. Fossil from Wanganui, New Zealand.

10. *Vibracella trapezoidea*, Reuss, × 12. Colony growing on *Orbitoides stellata*, Gümbel. Fossil from Bocca di Sciesa, Colle Berici, N. Italy.

11. *Conescharellina philippinensis*, Busk, × 25. Basal view showing small chambers with avicularia and others either broken down or incomplete. From Port Stephens, N.S.W.

12. Do. do. × 25. Section showing zoœcia and basal cells.

13. Do. do. × 25. Quadrant of upper surface showing some of the semilunar slits.

14. *Cupularia canariensis*, Busk, × 85. Showing connecting tubes to the zoœcia and to the vibracular chambers. From Madeira.

15. *Cupularia Lowei*, Busk, × 250. Chamber of peculiar body of the vibracula showing two small glands (*gl.*).

16. *Conescharellina conica*, Haswell, × 25. Calcareous section showing subsequent calcareous growth over the apex. From N.E. coast of Australia.

17. *Cupularia Johnsoni*, Busk, × 25. Under side of the cone showing spinous processes. From Madeira.

18. *Trochopora conica*, Def., × 12. Lower surface. From Salles (Gironde); Helvetian.

19. *Conescharellina angulopora*, T. Woods, × 25. Upper surface. There are two semilunar slits without the plate (*s.s.*). From off Port Stephens.

20. *Conescharellina conica*, Haswell, × 25. Lower surface. From N.E coast of Australia.

Fig. 21. *Conescharellina angulopora*, T. Woods, × 25. Lower surface. From Port Stephens, N. S. Wales.

22. *Conescharellina* prob. *cancellata*, Busk, × 25. Lower surface. From off Port Stephens.

PLATE 30.

Fig. 1. *Cupularia Lowei*, Busk, × 50. Decalcified preparation, looked at from the front. Through the membrane the bundles of muscles attached to it can be seen and they pass through the frontal pores.

2. Do. do. × 50. The same preparation focussed at a lower level. The circular opening is shown through which the polypide passes and the tubular connections from this opening to the neighbouring zoœcia. The polypide is faintly shown in the right-hand zoœcium.

3. Do. do. × 50. The same preparation seen from the dorsal surface. A line of muscles (*m.*) reaching down to the zoœcial chamber is seen, and the polypides are usually alternately right and left in each radial row of zoœcia.

4. Do. do. × 25. Dorsal surface showing pore at the end of the groove.

5. Do. do. × 85. Somewhat pressed down, so that the row of muscles are seen laterally.

6. Do. do. Lateral section; diagrammatic, showing rows of muscles attached to the lower membrane (*l.m.*) and to the zoœcial chamber (*z c*).

7. *Selenaria concinna*, T. Woods, × 25. From Port Stephens.

8. Do. do. × 50. Vibraculum.

9. *Selenaria concinna*, Busk, × 25. Showing central zoœcia and a few of the border zoœcia. From off Port Stephens.

10. Do. do. × 25. Section showing double expansion of a pore-tube under the supporting flake.

11. *Cupularia canariensis*, Busk, × 25. Central zoœcia with eight surrounding zoœcia. From Petit Tahou, Liberia.

12. Do. do. × 15. Under surface of same with large sand grain.

13. *Selenaria maculata*, Busk, × 325. Portion of vibracular seta showing spinous fringe on one side.

14. Do. do. × 150. Operculum from inside showing trabeculæ, and below the operculum two muscles attached to the frontal membrane.

15. Do. do. × 85. Size for comparison with previous figures.

16. *Lunulites capulus*, Busk, × 85. Vibracular seta.

17. *Trochopora conica*, Def., × 25. From Salles; Fossil.

18. *Conescharellina angustata*, d'Orb., × 25. From China (*A. W. coll.*).

19. *Conescharellina angulopora*, T. Woods, × 6. Showing growth over the apex.

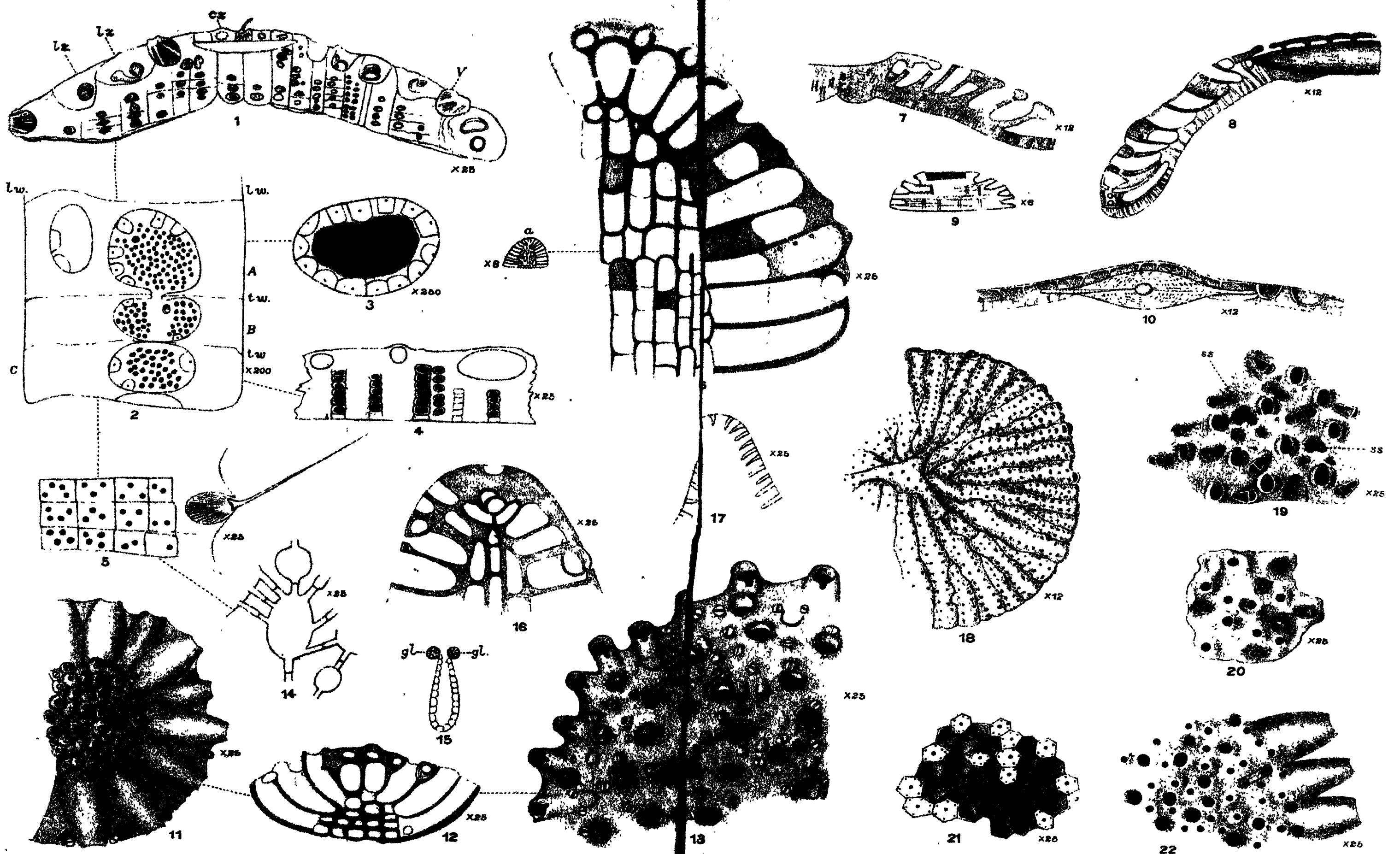
20. *Conescharellina philippinensis*, Busk, × 85. Decalcified to show the position of the zoœcial (*zc.*) and avicularian (*avc.*) chambers.

21. *Cupularia canariensis*, Busk, × 150. Base of seta and front wall of the vibracular chamber.

22. Do. do. × 150. Operculum seen from inside together with the frontal membrane showing trabeculæ.

23. *Cupularia Johnsoni*, Busk, × 150. Operculum from inside with the bordering ridge or trabeculæ united to the zoœcial border.

24. *Conescharellina philippinensis*, Busk, × 25. Young colony.



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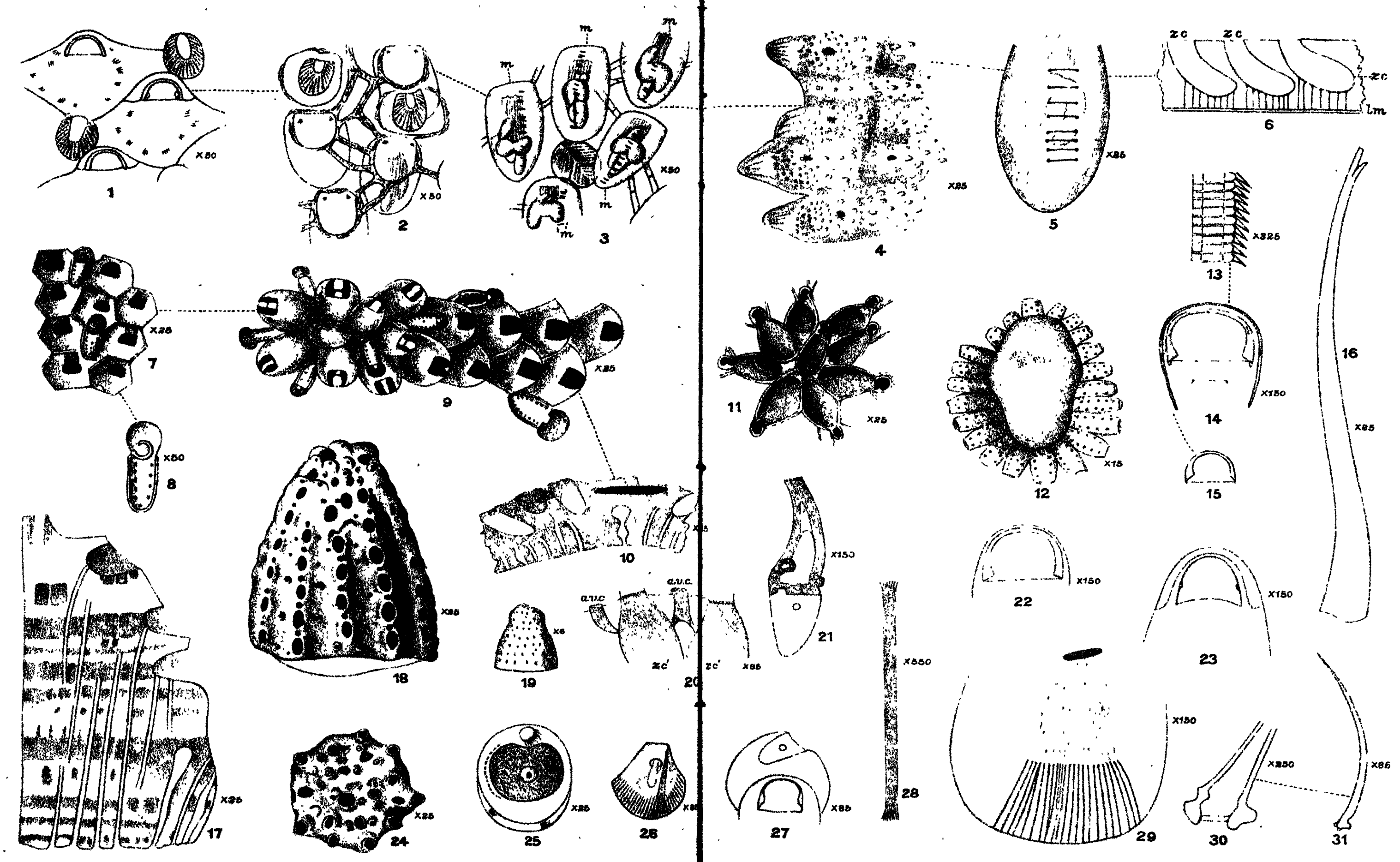

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Fig. 25. *Cupularia canariensis*, Busk, × 25. Ovum in zooecial chamber. Portion of remains of polypide (*p.*).

26. *Cupularia Lowei*, Busk, × 85. Vibracular chamber, showing the peculiar body ending at the thin circle in the membrane. One bundle of long muscles, as well as the short ones, is shown.

27. Do. do. × 85. Vibracular chamber above the zooecial chamber.

28. Do. do. × 550. Muscle of vibraculum.

29. Do. do. × 150. Muscles leading to fascia, which is attached to the base of the seta.

30. *Cupularia Johnsoni*, Busk, × 250. Base of seta.

31. Do. do. × 85. Seta.

On the Structure and Occurrence of Maxillulæ in the Orders of Insects.

By ALWEN M. EVANS, M.Sc. (Manch.), Dept. of Medical Entomology, Liverpool School of Tropical Medicine. (Communicated by Dr. A. D. IMMS, F.L.S.)

(PLATE 31, and 17 Text-figures.)

[Read 5th June, 1919.]

CONTENTS.

Introduction, p. 429, Apterygota, p. 430, Dermaptera, p. 433, Orthoptera, p. 434, Ephemeridæ, p. 435, Perlaria, p. 436, Psocidæ and Mallophaga, p. 437, Neuroptera, p. 439, Coleoptera, p. 442, Lepidoptera, p. 445, Trichoptera, p. 447, Hymenoptera Tenthredineæ, p. 448, Diptera, p. 451, Summary of Conclusions, p. 452, Bibliography, p. 454, Explanation of Plate 31, p. 456.

INTRODUCTION.

A QUARTER of a century ago Hansen (1893) originated the theory that the pair of appendages associated with the hypopharnyx of *Machilis* and other Apterygota is homologous with the maxillulæ of Crustacea (21)*. The theory has since been raised to the status of an established fact, chiefly by the embryological researches of Folsom. In the paper in which his results are recorded, Folsom (17. p. 116) stated that "The superlinguæ (maxillulæ) should hereafter be recognised as morphologically important structures, and be searched for in even the most specialised haustellate orders . . . . ."

Since this forecast was made its value has been proved by reasearches on the constitution of the hypopharynx in Coleoptera and Lepidoptera. In the larvæ of certain genera of these orders the presence of structures of undoubtedly maxillular nature has been demonstrated.

The present paper is a record of investigations whose object has been to determine as far as possible the occurrence of structures comparable with maxillulæ in the various orders of insects. In the haustellate orders only the mandibulate larvæ are considered. The Hemiptera, Mecaptera, and Thysanoptera are not dealt with. Some attempt is made to compare the form of maxillulæ characteristic of different orders and, where enough material has been available, to study the distribution and variation of these structures within the order.

I wish to express my gratitude to Professor S. J. Hickson, F.R.S., who has kindly allowed me to work in the Entomological Laboratory of the University of Manchester.

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* My attention has recently been called to the fact that Lubbock in his monograph of the Thysanura and Collembola recognises the maxillulæ as appendicular structures, referring to them as "a second pair of maxillæ."

I find it impossible to express how greatly I am indebted to Dr. A. D. Imms for the invaluable assistance he has rendered in innumerable ways. To him I owe the suggestion of the subject of investigation. I am glad to have this opportunity of thanking Dr. Imms for the immense amount of trouble he has taken in the furtherance of this work.

Terminology.—Folsom in 1899 furnishes a complete list of the various terms employed up to that date to designate the hypopharynx and maxillulæ. To these latter terms, proposed by Hansen, he objects on the grounds that they imply unproved homology. He proposed to call the median element of the compound "hypopharynx" the "lingua," and its lateral appendages the "superlinguæ." His objection to Hansen's terms can no longer hold after his own proof of the correctness of the assumption of this homology.

Investigators on the morphology of the mouth-floor in Endopterygota speak of the median portion as the hypopharynx and the lateral lobes projecting from or situated upon it as maxillulæ. These terms possess the advantage that they are free from the possibility of confusion with others used to designate portions of the labium. They will for these reasons be employed in the present paper.

APTERYGOTA.

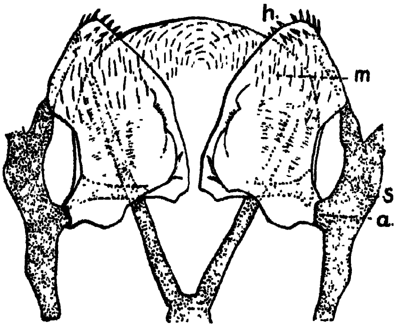
Machilidæ.—The maxillulæ are figured by Oudemans (35) under the name "Paraglossæ." They are described in some detail by Hansen (21. p. 31). They are, he says, independent of the hypopharynx near the base of which they are articulated to the skeleton of the head. He notes the "small single jointed palp," and observes that each appendage shows, towards the tip, a tendency to cleavage into two lobes. A detailed figure is given by Carpenter (6). He refers to the "spicules, ridges and pits" which occur on their surface, and states that the outer lobe of each is articulated with the basal sclerite. They have, he says, "all the appearance of a reduced pair of jaws."

Petrobius sp.—*P. oudemansi*, Carpenter (?). The headless remains of the specimens were kindly identified as far as possible by Professor G. H. Carpenter. Since these appendages are in *Machilidæ* in a less rudimentary condition than in any of the other insects considered in this paper, their structure in this species has been studied with some care. Observations made on simple dissections were supplemented by examination of preparations treated with potassic hydrate, and others, which in addition were stained with acid fuchsin.

The maxillulæ, which lie between the mandibles and first maxillæ, are seen, after the removal of these pairs of jaws, to stand on the floor of the mouth, above the base of the hypopharynx. Of this organ they obscure all but the extreme tip. Pl. **31** is drawn from a preparation in which the maxillulæ were pressed apart so as to expose the hypopharynx. This latter measures ·56 mm. in length. The length of the left maxillula is ·59 mm. and its greatest width 1·9 mm. A pair of long peduncles (*p.e.*) support the hypophyarynx.

The cavity of the maxillula was found to be undivided; the sutures separating the lobes consisting of no more than ridges and grooves in the upper wall only. Of these ridges, that which marks off the outer lobe, arises beyond the palp. At its base is the rounded, chitinous structure (*a.*) suggestive of an articulation. A short distance behind the apex of the inner lobe there projects from the depression between this and the outer lobe the curious structure (l_1), armed with six curved teeth, which point towards the surface of the maxillula; the portion of the palp (*p.*) beyond the lateral wall measures ·14 mm. in length.

Text-fig. 1.



Campodea lubbocki. Dorsal aspect. From a preparation stained with acid fuchsin. Pressure has been applied and the maxillulæ are displaced outwards. × 250. *a.* Articulation of maxillula. *h.* Hypopharynx. *m.* Maxillula. *s.* Supporting skeleton.

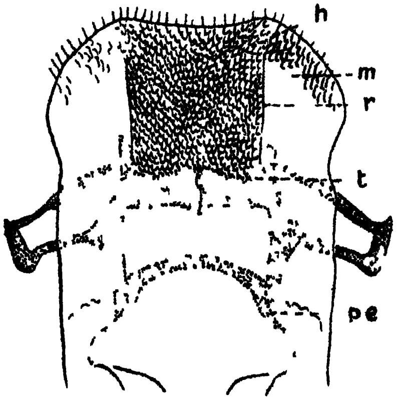
Campodeæ.—In his paper on the Campodeæ, Meinert (**32**) described the lingua and paraglossæ of *Japyx* and of *Campodea.* The lingua, he says, is small in the former genus and the paraglossæ large and bilobate. In the latter the appendages are large and flat, entirely covering the dorsal surface of the oval lingua. Hansen (**21**) states that the two genera are closely allied as regards the structure of the mouth-parts. He agrees with St. Traunfels that in *Japyx* the maxillulæ consist of an inner lobe, an outer lobe, and a three-jointed palpus. In dealing with these structures, in *Lepidocampa fimbriatipes* Carpenter (**8**) states his belief that this outer lobe and palpus were rightly referred to the maxillæ by Börner in 1908.

Specimens of *Campodea lubbocki* (Silvestri) (for the identification of which I am indebted to Mr. R. S. Bagnall) were collected at Fallowfield, Manchester.

The structure of the hypopharynx and maxillulæ is illustrated in text-fig. 1. The hypopharynx measures ·09 mm. in length and ·12 mm. in greatest breadth. In its natural condition it is almost obscured by the maxillulæ (*m.*), which are articulated at (*a.*) to a short branch of the skeletal support (*s.*). They are laminar, and can be removed entirely from the hypopharynx. The distal portion is triangular and the pointed apex furnished with sharp teeth directed inwards. The dorsal surface is covered with setæ, those of the anterior and inner areas being borne by scales arranged in rows. Each maxillula measures ·11 mm. in length and ·05 in total width.

Lepismida.—Hansen (21) states that in the structure of the hypopharynx *Lepisma* stands between *Machilis* and the Orthoptera. His statement is referred to by Carpenter (8. p. 13), who described the tongue of *Isolepisma* and the maxillulæ borne by it. These latter have "a roughened apex, with fine short bristles," and there is "no differentation into lacinia and galea." The tongue of *Lepisma saccharina* (text-fig. 2) is a broad membranous structure closely applied to the surface of the labium. It is supported distally by a system of sclerites, composed of elements corresponding to those of *Isolepisma.* The width at the base is ·2 mm. and the distance from the transverse bar (*t.*) to the anterior edge ·12 mm. The maxillulæ have become completely fused with the tongue, of the upper surface of which they form the lateral portions, being separated from the median scaly portion by longitudinal ridges (*r.*).

Text-fig 2



Lepisma saccharina Dorsal aspect of tongue. *h.* Hypopharynx. *m.* Its maxillular surface. *p e.* Peduncles. *r* Longitudinal ridge marking inner edge of maxillula *t.* Anterior transverse bar of skeletal system

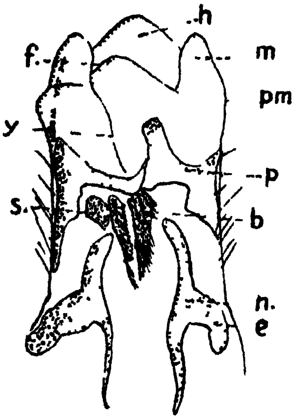
Collembola.—Maxillulæ appear to be present in all Collembola as a pair of delicate lamellæ intimately associated with the hypopharynx. A frequently occurring feature is the presence of a fringe of tooth-like projections or of setæ along the inner margin.

Isotoma palustris was regarded by Carpenter (6) as possibly one of the least specialised Collembola. He described at the apex of the maxillula an indication of cleavage into two lobes. Of the Achorutidæ *Anurida maritima* is the subject of Folsom's well-known work of 1900. Reference has already been made to his conclusions with regard to the nature of the superlinguæ. An exact account of their structure is to be found in the Monograph of Imms (24).

DERMAPTERA.

Forficula.—In his paper on *Hemimerus talpoides*, Hansen (22) devotes considerable attention to the hypopharynx and maxillulæ which he describes and figures in detail (pp. 70, 71, fig. 10). I have also been able to examine the hypopharynx of specimens of *Hemimerus hanseni*, Sharp, kindly determined by Professor Carpenter and collected by Dr. J. W. S. Macfie at Accra, Gold Coast. I found it essentially similar to that of *Forficula*. The main differences concern the degree of fusion of the maxillulæ with the hypopharynx, and the details of construction of the transverse elements of the skeletal support.

Text-fig. 3.



Forficula auricularia Dorsal aspect of tongue. × 80. *b* Brush-like sclerite. *f* Asymmetrical fold in dorsal wall of hypopharynx. *h.* Hypopharynx. *m* Maxillula. *n* Chitinous plate in inferior wall of pharynx. *p.* Transverse skeletal bar. *p m.* Chitinous rod in outer wall of maxillula. *s.* Small sclerite.

We find in *Forficula* a roughly oblong tongue (text-fig. 3) lying above the labium. It is produced distally into a median (*h.*) and two lateral (*m.*) membranous lobes, corresponding to the hypopharynx and maxillulæ respectively of *Hemimerus*, although each is considerably shorter in proportion to its width than are the corresponding organs in this latter genus. In one adult specimen they measured ·02 mm. in length and their width at the base was ·02 mm. The hypopharynx extended beyond the level of their bases to a distance of ·03 mm. and its greatest breadth was ·07.

Proximally the floor of the mouth bears the pair of asymmetrical sclerites (*n.*) from the side of which the plates (*e.*) extend downwards to be closely associated, at their ventral extremities, with the inner angle of the mandible. These sclerites have an exact counterpart in *H. hanseni*, Sharp, although in the latter case there is no sign of asymmetry. Anteriorly we find in *Forficula* a chitinous arch consisting of two asymmetrical sclerites (*p.*), the small piece (*s.*), and the curious setiferous median sclerites (*b.*), which will be referred to when we come to consider the Psocidæ and Mallophaga. In this position in *H. hanseni*, Sharp, however, we find only a single slender arch of chitin immediately above which the maxillulæ arise.

In all the specimens examined the dorsal wall at the base of the hypopharynx exhibited a tendency to form the curved fold (*f.*) whose apex lay considerably to the left of the median line. A similar fold at the base of the left maxillula gave this organ a bilobed appearance.

The ventral surface of the tongue is stiffened by a continuous plate of yellow chitin. This plate extends forwards to a short distance behind the base of the hypopharynx. It is associated at its anterior lateral corners with a slender chitinous rod (*p.m.*) which supports the external wall of the maxillula. In this position I found a more plate-like sclerite in *H. hanseni*, Sharp.

It is probable that *Forficula* is derived from a form in which the hypopharynx and its lateral appendages originated as far back as the transverse sclerite. Such a condition would resemble more closely that of *Hemimerus*. This supposition is supported by the presence of a faintly marked suture (*y.*) extending back from the inner angle of the left maxillula to this skeletal bar.

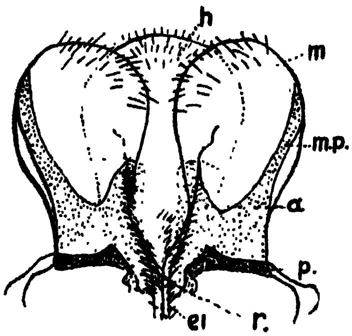
ORTHOPTERA.

Folsom (**17.** p. 115) gives an account of the hypopharynx of Orthoptera. The lingua he says "corresponds exactly with the lingua of Apterygota." He finds that the chitinous supporting stalks described by Miall and Denny are comparable to those in Apterygota. In *Melanopus femoratus*, Folsom discovered "superlinguæ" as "large dorso-lateral rounded lobes intimately united with the lingua." He notes the evidence of the presence of lingua and superlinguæ in Packard's figure of *Anabrus*, Packard (**36**). The tongue of Blattidæ is described by Mangan (**29.** p. 3, pl. i. fig. 1). "The free tip," he says, "is furnished at the sides with a pair of elongate plates (Z) which carry bristles, and are continuous behind, as thin rods, round the opening of the salivary duct; . . . The position of . . . (Z) is conformable with the idea that they may represent a pair of maxillulæ." Schimmer (**39**) describes the hypopharynx of the Gryllid *Myrmecophila.* On the ventral surface are borne a pair of elliptical plates covered with fine setæ. Mjoberg (**34**) has no hesitation in homologising these plates with the so-called "lingual glands" associated with the hypopharynx of Psocidæ. The nature of these latter structures will be discussed below, but here it may be remarked that Enderlein (**15**) regards them as maxillulæ.

EPHEMERIDÆ.

As the well-known figure of the lingua and superlinguæ of *Heptagenia* Vayssière (**45**) makes evident, these structures attain a very well-developed condition in the Ephemeridæ. No attempt had at that time been made to homologise the lateral appendages with maxillulæ. Vayssière was, however, so much impressed by their appendicular appearance that he proposed to regard the Ephemeridæ as insects provided with a secondary labium, consisting of the median "langue" together with its "deux appendices." Eaton, in his monograph of 1883, figures the "tongue" and "paraglossæ" of the nymphs of a large number of Ephemeridæ. Though the latter organs show considerable variation in size relative to the former, they are never wholly absent. Hansen (**21**) refers to them as maxillulæ. This view of their nature is supported by the figure of the head of a young larva of *Ephemera*, in which Heymons (**23**. Taf. ii. fig. 29) clearly shows that they are originally distinct from the hypopharynx. From his description (p. 22) it is evident that Heymons regards the appendages as lateral portions of the hypopharynx.

Text-fig. 4.



Chloëon dipterum. Tongue of nymph. × 90. *a.* Articulation of maxillula. *h.* Hypopharynx. *m.* Maxillula. *m.p.* Plate in ventral wall of maxillula. *p.* Transverse sclerite at base of maxillula. *r, ei.* Setose ridges at base of hypopharynx.

Folsom (17. p. 116) is convinced of their homology with the lingua and superlinguæ of *Anurida*, which in a certain stage of their development bear a great resemblance to Heymons' figure of *Ephemera*.

Chloëon dipterum.—The oval hypopharynx (text-fig. 4) measures ·3 mm. in length and ·21 mm. in breadth at the widest part. The maxillulæ (*m.*) resemble this structure in shape and size, and in the membranous nature of their walls. Each measures ·2 mm. in width and extends ·3 mm. beyond the sclerite (*p.*). Each maxillula is supported ventrally by a curved chitinous plate (*m.p.*), which is proximally merged with the chitinised posterior portion of the wall of the hypopharynx.

The inner edges of the maxillulæ are continuous with a pair of convergent setose ridges (*r.*), which extend backward along the upper surface of the hypopharynx. Outside these occur a second pair of ridges (*ei.*) also bearing setæ, whose distal portions lie on the upper surface of each maxillula.

PERLARIA.

Packard (36) describes the hypopharynx of Perlidæ as "an unusually large tongue-like mass nearly filling the buccal cavity." I have examined this organ in the adult of a species of *Perlodes* closely resembling *P. dispar*, and find that it answers to the above description. No signs of maxillulæ were discovered.

The larvæ of the two sub-orders *Plecoptera filipalpia* and *Plecoptera setipalpia* Klapalek (27) are distinguished by the structure of the labium. This in the former group is apparently less specialised than in the latter. An examination of the hypopharynx in the two genera *Leuctra* and *Nemura* of the Filipalpia and *Perlodes*, *Chloroperla*, and *Perla* of the Setipalpia suggests that the form of this organ offers a further distinction *.

Nemura.—In the larva of an undetermined species of this genus the hypopharynx (text-fig. 5) is a much-rounded structure convex dorsally. The surface is thin and membranous. It measures ·13 mm. in length and ·2 mm. in width in a specimen with length of abdomen 2·88 mm. From its dorsal surface project two large lobes (*m.*) measuring ·09 mm. in length and ·05 mm. in width, which extend laterally some distance beyond the hypopharynx, and whose cavities are confluent with that of the latter. Ventrally a chitinous plate (*p.m.*) supports the free portion of each lobe. Proximally the dorsal surface of the hypopharynx (or ventral wall of the pharynx) bears a pair of setose ridges (*r.*). Each ridge is distally continuous with the inner margin of the lateral lobe. Thus the position of these ridges agrees strikingly with that of a similar pair which have been described in *Chloëon*, if we regard the structures (*m.*) as the homologues of the maxillulæ of this Ephemerid. Further comparison gives additional grounds for this assumption. The lateral lobes are in both cases fused with the hypopharynx on its dorsal surface. They extend beyond it laterally. In both cases they are supported ventrally by a chitinous plate, and a transverse bar of chitin (text-figs. 6 & 7) marks the line of junction to the upper surface of the hypopharynx.

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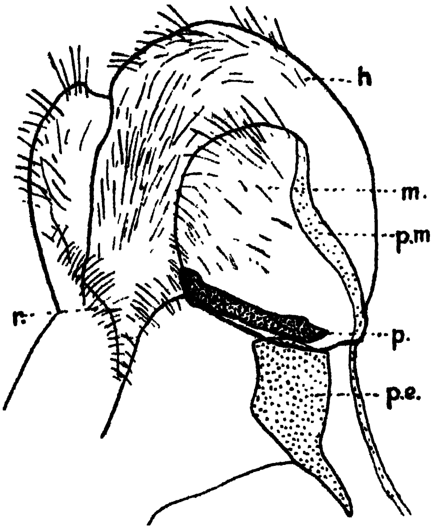
* The only traces of maxillulæ associated with the large fleshy tongue of larval Setipalpia were a pair of very small setiferous lobes, but in the Filipalpia these organs were large, and well developed and similar in both genera examined.

The difference existing between *Nemura* and *Chloëon* in respect of these organs appears therefore to be concerned merely with the degree of fusion of their adjacent surfaces.

Text-fig. 5.



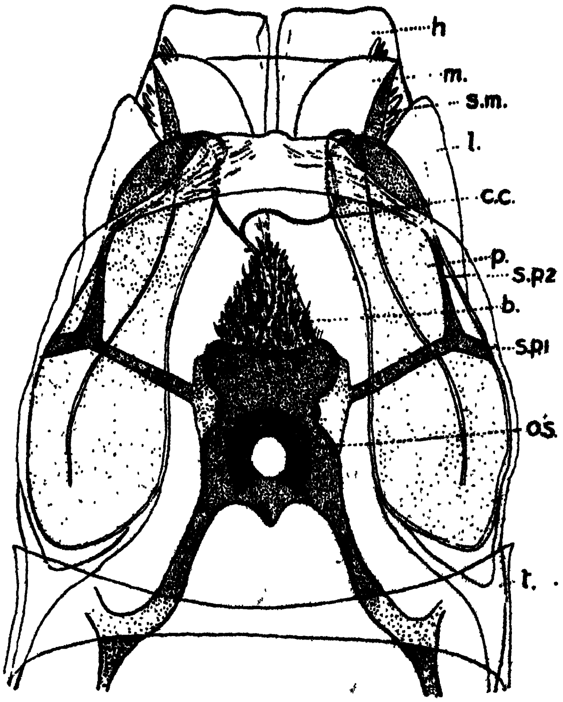
Nemura sp. Tongue, dorso-lateral aspect. × 250. *h.* Hypopharynx. *m.* Maxillula. *p.* Transverse sclerite at base of maxillula. *p.m.* Plate in ventral wall of maxillula.

PSOCIDÆ AND MALLOPHAGA.

The tongue of Psocidæ (text-fig. 6) and Mallophaga bears a pair of oval, or sole-shaped, structures (*p.*) as to the nature of which considerable controversy exists. They were described by Burgess (5) in the Psocidæ and termed "lingual glands," but Burgess suggests that this term might not correctly express their nature. The chitinous cord (*c.c.*) proceeding from each, which unite, and pass backwards as a single cord, to be attached to the "bonnet-shaped" skeletal structure (*o.s.*), are referred to as "ducts" of these glands. Among later writers this interpretation has been followed by Snodgrass (43) and Shipley (41). The "glands" are, however, considered to be chitinous thickenings of the hypopharynx by Grosse (19), Mjoberg (34), and Cummings (10). Enderlein (15) expressed the opinion that the "glands" are appendages homologous with the maxillulæ of Collembola, while Borner (4) calls them the "fulturæ" or lingual stalks, and says that the maxillæ are represented by a pair of membranous lobes attached to the tongue.

The mouth-parts of British Psocidæ are, owing to their minute size, exceedingly difficult of dissection, but, through the kindness of Dr. Imms, I have been able to examine specimens of a very large species which is a native of India. The hypopharynx, whose walls are of very delicate membrane, is figured (text-fig. 6) from the dorsal surface. The ventral wall is thickened laterally to form the paired, convex, sole-shaped plates of yellow chitin (*p.*) (seen by transparency), the so-called "lingual glands." The size of the specimens made it possible to dissect out the hypopharynx and open up

Text-fig. 6.



Large Psocid. Tongue, dorsal aspect. The plates *m.* and chitinous cord *c.c.* are seen through the membranous dorsal surface of the hypopharynx and maxillula. × 250. *b.* Brush-like sclerite. *c.c.* Chitinous cord = "duct." *h.* Hypopharynx. *l.* Lobe of hypopharynx. *m.* Maxillular lobe of hypopharynx. *p.* Chitinous plate = "lingual gland." *o.s.* Œsophageal sclerite. *s.m.* Sclerite rising from apex of plate (*p.*) and associated with *m.* *t.* Tendon.

the dorsal wall, so that there was no doubt at all as to the exact position of these plates. Chitinous sclerites (*s.p.*1) and (*s.p.2*) connect the outer edge of each with the upper surface of the hypopharynx. Distally arise sclerites (*s.m.*) reaching to the apices of the delicate lateral lobes (*m.*). These lobes bear the same relation to the hypopharynx as do the maxillæ of *Forficula*, and it seems highly probable, as Borner (4) suggested, that they represent these appendages in a somewhat modified condition. A pair of membranous lateral projections (*l.*) arises behind them and may possibly represent a basal lobe of the maxillulæ.

Attached to the base of each plate (*p.*) are the forks of a strong tendon (*t.*), whose presence strongly suggests that the chitinous structures associated with the hypopharynx are mechanical in function.

In order to settle the question whether or not gland tissue is to be found associated with the plates (*p.*), nymphal specimens of a small British species of the Psocina group were sectionized. The fixatives employed were Carnoy's fluid (cold) and Gilson's fluid (hot), and the sections were stained with Heidenhain's iron hæmatoxylin in some cases and Grenacher's hæmatoxylin and eosin. The tissue lying between the plates and the upper surface of the tongue was indistinguishable in structure from that seen in many parts of the other mouth appendages. In transverse sections through the tongue no histological difference could be detected between the median portion and that lying above the plates. This investigation, therefore, lends support to the assertion that these latter structures are not in any way glandular or associated with glands. They are to be looked upon as thickened parts of the ventral wall of the tongue, which may possibly have originated as lingual stalks, or as the basal portions of maxillulæ which have become incorporated into the hypopharyngeal wall.

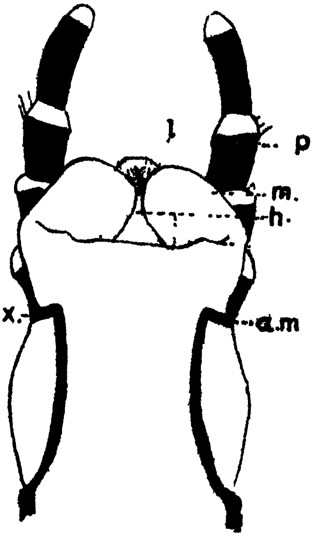
NEUROPTERA.

Raphidia.—Adult forms of a species of *Raphidia* were examined and in them the hypopharynx revealed some features of great interest. Text-fig. 7 (p. 440) represents the labium and floor of the mouth as seen when viewed from the dorsal surface; (*p.*) is the labial palp and (*l.*) the bifid, dorsally flexed, extremity of the single median endite borne by the mentum. See Westwood (**46**. pp. 45–56). The opening of the salivary duct occurs above the labium and ventral to the median fleshy projection (*h.*) in the floor of the mouth. This rounded lobe I regard as the hypopharynx or its distal portion. It is almost obscured by two others of similar membranous texture (*m.*). Each lateral lobe measures ·14 mm. in length and ·11 mm. in width. In texture and relative positions these three lobes bear a decided resemblance to the median hypopharynx and lateral maxillulæ of *Forficula*. Since the Neuroptera are amongst the less specialised Endopterygota it is possible that a true homology underlies this similarity.

In the larvæ of *Sialis* and *Chrysopa* the hypopharynx was not found to bear any distinct indications of maxillulæ.

Sialis.—The labium of the adult *Sialis* is described by Westwood (**46**. vol. ii. p. 50). He states that the true labium, "ligula," does not extend beyond the palpi but is "internally dilated." Packard (**36**. p. 73) describes the lingua of *Sialis*. It is, he says, short rounded and little developed. He notes the presence of sensory hairs at the edge similar to those borne by threads of the maxillary and labial palpi.

Text-fig. 7.



Raphidia sp. Tongue, dorsal aspect. × 90. *a.m.* Chitinous bar arising from mentum. *h.* Hypopharynx. *l.* Ligula. *m.* Maxillula. *p.* Labial palp.

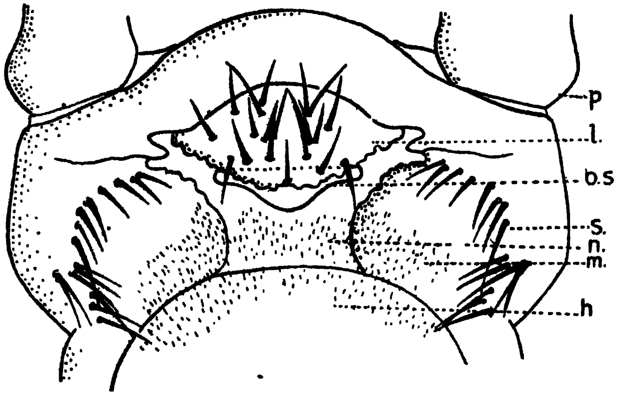
In text-fig. 8 (p. 441) this structure together with the hypopharynx (*h.*) is shown as viewed from before. (*l.*) is the anterior border of the labium (ligula). At each side the labium is connected internally to the palp (*p.*), with a large rounded lobe bearing small fine setæ and at the end a row of long stiff hairs: apparently those referred to by Packard. Viewed from the dorsal surface these lobes present much the same appearance as the similarly located structures in *Raphidia*. They may therefore be maxillulæ. This view as to their nature is based partly on the fact that here as in *Raphidia* their texture resembles that of the mouth-floor and differs from that of the "ligula."

Hemerobius.—The appearance of the mouth-floor of an adult specimen of *Hemerobius* sp. as seen from the dorsal surface is illustrated in text-fig. 9 (p. 442). It is seen that from the membranous hypopharynx (*h*) arise a pair of lateral lobes (*m.*), the surface of which, like that of the hypopharynx, is covered with minute setæ (not shown in the figure). These lobes are, according to my interpretation, maxillulæ which have assumed a somewhat ventro-lateral position with regard to the hypopharynx.

Later a fresh specimen of *Chrysopa flava* was examined. The labium and hypopharynx resembled those of *Hemerobius* in general characters and also in their relative position. Prominent lateral plates were present at the sides of the hypopharynx, entirely clothed with long fine setæ. They could be reflected outwards to a considerable extent.

It was hoped that investigation of the hypopharynx in larval and adult Neuroptera might throw light on the origin of the condition in which it occurs in some of the mandibulate forms of Endopterygota. Now, let us suppose that the labium of *Forficula* were so reduced as to bear but a single median endite, and its sides fused with those of the tongue. The resulting structure would bear a distinct resemblance in constitution and appearance to the condition in *Raphidia*. These considerations suggest that in the latter such reduction and fusion have taken place. The maxillulæ in *Forficula* would, moreover, occupy precisely the same position with regard to hypopharynx and labium as do the lobes (*m.*) in *Raphidia*. It is therefore probable that these latter are wholly or partially the persistent maxillulæ.

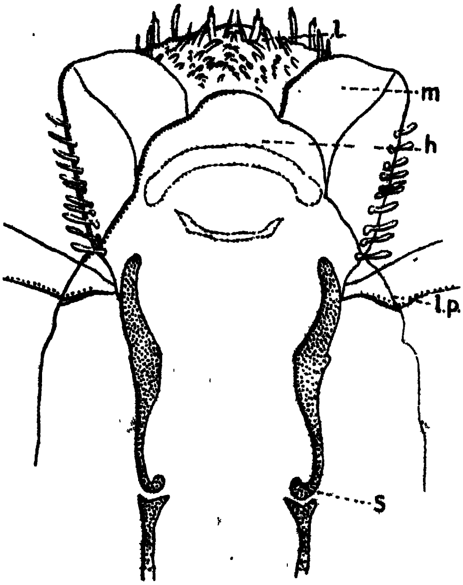
Text-fig. 8.



Sialis lutuaria. Labium and hypopharynx viewed from before. *h*. Hypopharynx. *l*. Ligula of labium. *m*. Maxillular lobe. *p*. Palp. *o.s*. Opening of salivary duct. *s*. Setæ bordering maxillula ventrally.

In a later part of the present paper I have attempted to demonstrate a close correspondence between the construction and arrangement of the hypopharynx and labium in a Tenthredian larva and that of *Sialis*. I have further suggested a possible mode of derivation of the condition in larval Lepidoptera and Trichoptera from one less specialised such as we found in larval Tenthredineæ. If there is any foundation for these suggestions then the Neuropterous types studied have afforded some clue to the mode of development of the highly specialised labio-hypopharyngeal structure of Lepidoptera from the free tongue and generalised labium of *Forficula*. They have, further, made it apparent that the possession of a pair of lobe-like projections is a feature of the hypopharynx in the Neuropterous forms studied. In dealing with the Tenthredineæ, reasons are given for assuming that the corresponding structures (*m.*) in that family are homologous with the maxillæ of Lepidopterous larvæ. I suggest, therefore, that in Neuroptera we find a condition of hypopharynx and maxillulæ intermediate between that of *Forficula* and larval Lepidoptera.

Text-fig. 9.



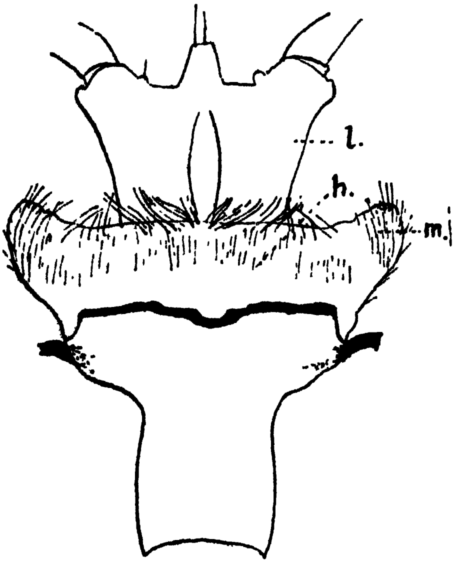
Hemerobius sp. Labium and hypopharynx, dorsal aspect. *h.* Hypopharynx. *l.* Dorsally flexed ligula. *l.p.* Labial palp. *m.* Maxillula. *s.* Sclerite supporting hypopharynx.

COLEOPTERA.

In the larva of *Helodes* Carpenter and McDowell (9. pp. 373–96) have described and figured a pair of articulated appendages, one at each side of the hypopharynx.

Homologous though reduced structures were found in *Dascillus*. These again were represented in a further reduced condition in the larva of the Lamellicorn *Geotrupes*. In a similar situation on the left side of the hypopharynx of the larval *Phyllopertha* occurred a very small lobe bearing teeth, a scarcely recognisable maxillula. In each of these cases it appears that the hypopharynx is membranous and is supported by a system of chitinous sclerites. It covers almost the whole of the surface of the labium to which it is fused or sutured in front. Of a totally different character is that of the larval *Pterostichus* described by Carpenter (7. p. 213, fig. 6). The anterior border is here broad transversely, set with long setæ and not united to the labium. Where this border comes into close proximity to the base of the maxilla it bears a small setose projection. This is regarded as a maxillula, agreeing as it does in position with the process described by Magan (1912) in larval Dytiscidæ.

Text-fig. 10.



Nebria brevicollis. Hypopharynx and labium, dorsal aspect. × 90.
h. Hypopharynx. *l.* Labium. *m.* Maxillula (left).

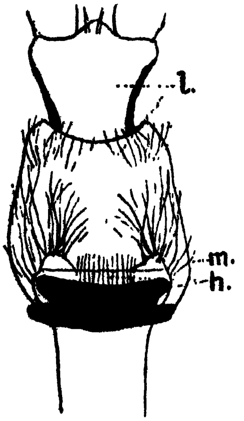
This latter type of hypopharynx I have found to occur in a modified form in larvæ of Staphylinidæ, Elateridæ, and the Malacoderm *Telephorus lituratus*. In other larvæ examined, Coccinellidæ, Tenebrionidæ, Chrysomelidæ, Cerambycidæ, and Curculionidæ, the structure was of the soft membranous character supported by sclerites. In the former group the labium extended considerably beyond the hypopharynx, and was not fused therewith anteriorly as was the case in the latter group.

In the Carabid, *Nebria brevicollis* (text-fig. 10), the larval hypopharynx (*h.*) is produced at the corners into two prominent lobes (*m.*) identical in position with the maxillulæ of *Pterostichus*. Apparently they are homologous with these appendages. Each measured ·09 mm. in width, and the combined width of maxillulæ and hypopharynx was ·6 mm. No distinct suture separating the maxillula from the hypopharynx could be detected. The maxillulæ here were more prominent than in the larvæ of *Pterostichus* and *Carabus violaceus* which were examined.

In various larval Elateridæ the hypopharynx was examined and great uniformity of construction was found to exist.

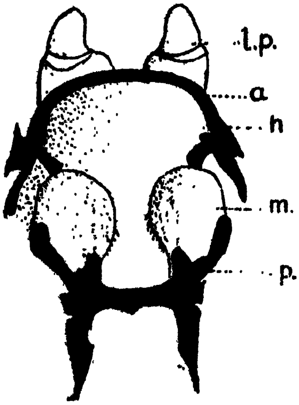
The condition seen in *Campylus linearis* will serve to illustrate the type. The hypopharynx (text-fig. 11), which is of stiff chitin, is supported by a stronger transverse chitinous plate. Its anterior border is independent of the underlying surface of the labium. It bears a pair of triangular plates (*m.*), measuring at the base ·05 mm. These I regard as vestigial maxillulæ from considerations based on a comparison with those of *Pterostichus*. The combined width of the hypopharynx and maxillulæ is ·24 mm. Each of the latter carries long, fine hairs which are mingled with similar but shorter hairs borne by the labium and by the basal portions of the maxillæ.

Text-fig. 11.



Campylus linearis. Labium and hypopharynx, dorsal aspect. × 90. *h.* Hypopharynx. *l.* Labium. *m.* Maxillula.

Text-fig. 12.



Anatis ocellata. Labium and hypopharynx, dorsal aspect. × 55. *a.* Anterior skeletal system. *h.* Hypopharynx. *l.p.* Labial palp. *m.* Maxillula. *p.* Posterior skeletal system.

The larva of *Telephorus lituratus* is described by Miss O. M. Payne (38). From pl. 2. figs. 14, 15, in which the hypopharynx is shown, it seemed that this structure was very similar to that of Elateridæ. Examination of the mouth-parts of a specimen confirmed this supposition. I discovered hidden by the long hairs which clothe the hypopharynx and labium a pair of very minute triangular projections situated at each side of the anterior border of the hypopharynx.

The similarity in character of the hypopharynx and maxillulæ and their relations with the labium in species of the Carabidæ, Dytiscidæ, Elateridæ, and Malacodermidæ gives support to the conclusions reached by Gahan (18) regarding the affinities of the Coleopteran families. This author states that the Adephaga, including the Carabidæ and Dytiscidæ, is the most primitive group of the Coleoptera, and that the Malacoderms are a primitive family of the Polyphaga, and gave rise to the Elateridæ to which they are closely related.

I am indebted to Dr. Imms for specimens of the Coccinellid larva, *Anatis ocellata*. The hypopharynx (text-fig. 12) possesses a membranous, greatly convex, surface covered with minute spines. It is strengthened by an anterior (*a.*) and a posterior (*p.*) skeletal system. Supported in the angle between the two anterior arms of the latter arises on each side a rounded lobe (*m.*). Each measured ·11 mm. in width, and the greatest width of the hypopharynx is ·32 mm. These paired lobes may be compared in form (though they do not bear spines), and position upon the hypopharynx with the vestigial maxillulæ of *Geotrupes*.

A condition very similar to that last described was met with in the larva of *Doryphora decemlineata* where, however, the lobes were of much larger extent, practically covering the surface of the hypopharynx.

The hypopharynx in *Tenebrio mollitor* and *Otiorhynchus sulcatus* was found to possess indefinite paired dorsal lobes, which, however, could not with any certainty be looked upon as maxillulæ.

LEPIDOPTERA.

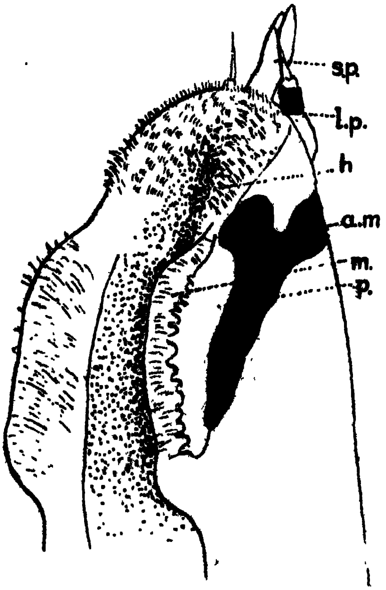
De Gryse (12. pp. 173–179) records the results of exhaustive investigations on the hypopharynx in a large number of Lepidopterous larvæ. On p. 174 he makes the generalisation that in larval Lepidoptera the maxillulæ "essentially present the appearance of protruding fleshy lobes, covering the floor of the buccal cavity wholly or in part only, ... These lobes are generally clothed with flexible lashes, with hairs or with rows of strong spines. . . . . . In many instances the lobes are also furnished with chitinous blades . . . . ." A feature common to the types described is the presence of a chitinous bar or "arm" arising from the mentum and at its distal end associated with the fleshy lobe.

I have examined the hypopharynx of a number of species of Lepidoptera belonging chiefly to the families Nymphalidæ, Pieridæ, Geometridæ, Noctuidæ, Lasiocampidæ, Pyralidæ, and Tineidæ. In most cases there was little that called for comment.

All the Noctuæ observed were found to agree remarkably closely with the condition found in *Mamestra persicariæ*. The right maxillula of *M. persicariæ* (text-fig. 13) measures ·51 mm. in length from the point (*x*.) From this level to the apex of the hypopharynx the distance is ·88 mm. *A thinly chitinised plate (p.) supports the outer wall of the maxillula to* which it is closely applied. It is fringed with freely projecting teeth. The greatest width of the left lobe is ·2 mm. The mental arm (*a.m.*) supports the chitinous plate for the greater part of its length.

The Rhopalocera investigated were not found to be strikingly different in the character of the hypopharynx from the Heterocera. In *Vanessa urticæ* this structure was of a form commonly occurring amongst the latter group. This type, represented by *Lagoa crispata*, De Gryse (12. pl. 17. fig. 1), is found in both micro and macro-lepidoptera (p. 176). The fleshy lobes are "covered with spines but devoid of all traces of blades."

Text-fig. 13.



Mamestra persicariæ. Labium and hypopharynx, dorso-lateral aspect. × 55. *a.m.* Mental arm. *h.* Hypopharynx. *lp.* Labial palp. *m.* Maxillula. *p.* Plate supportiing outer wall of maxillula. *s.p.* Spinneret.

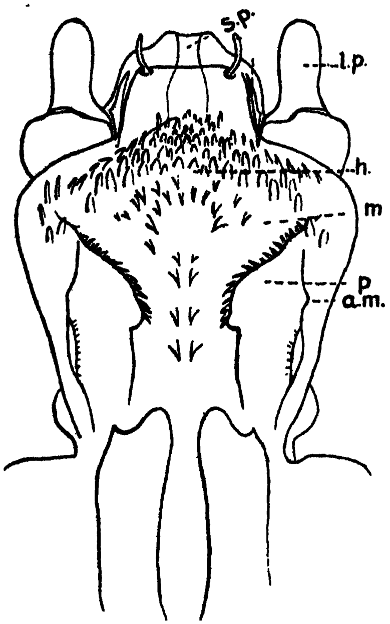
In *Pieris brassicæ* and *Philosamia cynthia* the maxillular lobes are very large in proportion to the hypopharynx, the proximal half of which they completely covered.

Considerable attention was devoted to examination of the condition of the hypopharynx in *Hepialus humuli.* Although the family to which this species belongs is in many respects primitive the hypopharynx is apparently considerably specialised. It does not seem to afford any clue to the original form of the maxillulæ in Lepidopterous larvæ. The whole of the mouth-floor is remarkably soft, rounded and membranous, and the areas of chitinization very small. A pair of lateral membranous protuberances were too indefinite in character to be homologised with maxillulæ.

TRICHOPTERA.

The hypopharynx has been investigated in eruciform larvæ of *Phryganea* and Limnophilidæ and in the campodeiform *Rhyacophila* and *Hydropsyche.* It was found in most cases to bear a general resemblance to that of Lepidoptera. Its dorsal wall, forming the floor of the mouth, is produced distally to form a conical spinneret. Laterally its walls are continuous with those of the labium. With the exception of *Phryganea* all the examples investigated were found to be constructed on a common plan, which can be best described by a consideration of the condition in a species referable to the genus *Rhyacophila.*

Text-fig. 14.



Rhyacophila sp. Labium and hypopharynx, dorsal aspect. × 250. *a.m.* Mental arm. *h.* Hypopharynx. *l.p.* Labial palp. *m.* Maxillular lobe. *p.* Plate supporting outer wall of lobe. *s.p.* Spinneret.

The hypopharynx (text-fig. 14) measures ·25 mm. in length and ·22 mm. in greatest width in an almost fully-grown larva. In its median portion the upper surface is thrown into a pair of convex ill-defined lobes (*m.*) set with stout curved spines. Each is supported externally by a chitinous plate (*p.*) measuring ·05 mm. in length and ·03 mm. in breadth. The free edge of this plate is furnished with long hook-like spines. It arises from a chitinous lateral expanse (*a.m.*). This latter is seen to be continuous ventrally with the thickened portion of the mentum and is apparently homologous with the chitinous "arms of the mentum" in Lepidoptera. (In the larva of a Limophilid a narrow bar of chitin is found in this situation.) The condition of the mouth-floor in *Hydropsyche* sp. was similar to that of *Rhyacophila* sp.

It has been shown that paired lobes associated externally with chitinous plates occur in widely separated families of Trichoptera. This evidence seems to suggest that the possession of these structures is a feature characteristic of Trichopterous larvæ with certain exceptions. The hypopharynx, when these structures are present, is comparable in constitution to that of the more generalised Lepidoptera. In addition to the setiferous lateral lobes, it is characterised in both orders by (1) the possession of a conical spinneret, (2) the presence of chitinous arms extending from the mentum and associated dorsally with the exterior of the base of the lobes, and (3) the membranous rounded nature of the floor of the mouth. Thus the hypopharynx of Trichoptera is seen to be constructed on a plan fundamentally similar to that of Lepidoptera. The maxillulæ of the latter order are therefore in all probability represented in Trichoptera by the similarly located lobes (*m.*).

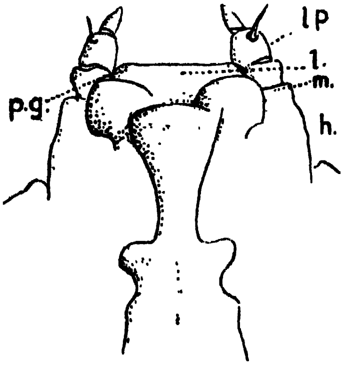
HYMENOPTERA TENTHREDINEÆ.

A vertical section through the head of *Hylotoma rosæ* Berlese (1. p. 522, fig. 595) shows that the duct of the labial or spinning gland runs above the labium to open above its extremity. Dorsal to the duct is seen a fold which constitutes the mouth-floor. The distal portion of this fold is, in all probability, the hypopharynx in Tenthredinian larvæ.

In a recent paper on the immature stages of the Tenthredinoidea McGillivray (31) fully describes and figures the mouth-parts of *Pamphilius dentatus*. It is stated that in *Pamphilius*, "On the dorsal surface of the ligula and laterad of the labial palpi, there is on each side a protuberance, a paraglossa. Between the labial palpi and arising on the ental surface, there is a prominent lobe which represents the glossa. The glossa has been modified into a spinneret (figs. 9, 13, sp.) for the opening of the duct of the silk glands." In fig. 13 the spinneret is seen as a structure projecting beyond the ventral surface of the ligula. It is therefore probably more highly developed than in the forms to be described.

This structure has been examined in various species, and considerable diversity was found to exist. Perhaps the simplest condition was that met with in *Selandria sixii*. The anterior portion of the labium (text-fig. 15) bears the three-jointed palps, and is scarcely differentiated into a median (*l.*) and two lateral portions (*p.g.*). The labium forms the ventral wall of a wide depression (*f.*) at the base of which is the end of the spinning duct. Dorsally this funnel is bounded by a rounded chitinous protuberance (*h.*), which is connected laterally with a similar pair of lobes (*m.*) closing in the sides of the funnel. They are the "glossa" and "paraglossæ" respectively of McGillivray (31). Each lateral lobe measures ·18 mm. in length and ·16 mm. in breadth. From their position in the floor of the mouth, and above the labial duct, I conclude that the median structure is the hypopharynx, and that the laterally associated pair may be maxillulæ or, at least, partly maxillular in constitution.

Text-fig. 15.



Selandria sixii. Labium and hypopharynx, dorsal aspect. × 55. *h.* Hypopharynx. *l.* Ligula. *m.* Maxillula. *l.p.* Labial palp. *p.g.* Paraglossæ.

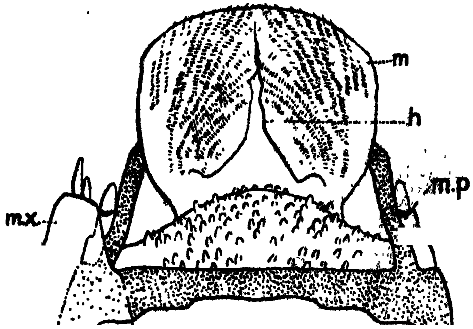
The mouth-parts of the larva of *Nematus Erichsonii* are typical of those of the majority of Tenthredineæ investigated. The surface of the hypopharynx and its dorso-lateral lobes is membranous and of rounded indefinite form.

The larva of *Fenusa melanopoda* was found mining the leaves of alder-trees. When mature it measures 9 mm. in length. The internal structure of the head bears a striking resemblance to that of the young *Acrocecrops* Heinrich and De Gryse (*loc. cit.* pl. 3. figs. 1 & 2). The mouth-parts are in both cases reduced and are associated with slender skeletal rods traversing the entire length of the head.

The mouth-floor of *Fenusa melanopoda*, viewed from above, presents the appearance shown in text-fig. 16. Between the vestigial labial palpi (*m.p.*) projects the rectangular flat membranous structure (*h.*). Since this structure lies above the labial duct it is here considered to be the hypopharynx. It is supported laterally by two arms of the skeletal system. The length is ·08 mm. and the greatest width ·09 mm. The dorsal surface is markedly convex and bears two large convex plates (*m.*) covered with rows of minute spines. I regard these plates as maxillulæ, which have become flattened in accordance with the dorsi-ventral compression of the head.

A comparison between the anterior aspect of the labium and hypopharynx of *Sialis* and *Selandria* (text-figs. 8 & 15) reveals a close agreement with regard to the arrangements of the constituent elements. The salivary opening in both cases causes a slit-like depression above the border of the labium.

Text-fig. 16.



Fenusa melanopoda. Hypopharynx and maxillulæ, dorsal aspect. The maxilla is indicated on the left side only. × 400. *h.* Hypopharynx. *m.p.* Labial palp. *m.* Maxillula. *mx.* Maxilla.

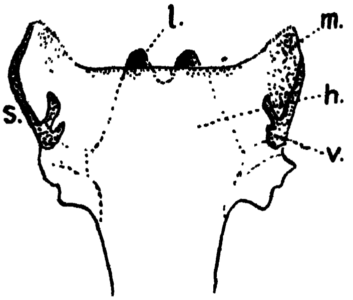
Dorsal to it is a median lobe, the hypopharynx, whose lateral lobe-like expansions form the lateral walls of the depression. These latter are associated with the labium at each side behind the base of the palps. In *Sialis*, however, the ligula of the labium exists as a definite setose plate which its not represented in *Selandria*. This comparison points to the conclusion that the labium and hypopharynx of Neuroptera and larval Tenthredineæ are constructed on the same fundamental plan.

In discussing the labial gland of Tenthredinian larvæ, Berlese (1. p. 522) described its termination "sotto la lingua in una specie di filiera." This leads us to enquire how far the condition here may be compared with that of Lepidoptera.

We have noticed that the labium in larval Tenthredineæ is in a considerably reduced state, while in Lepidoptera it has become almost unrecognisably modified to form the basal portion of the spinneret. Now in larval Trichoptera the spinneret is intermediate in development between that of Lepidoptera and the incipient condition of Tenthredineæ. It therefore appears likely that in the two orders in which a spinneret occurs it is derived from such raw materials as are afforded by the state of the hypopharynx and labium of Tenthredineæ. Assuming this to be the case, the hypopharynx of the latter order is homologous with the proximal portion of that of Lepidoptera. We should then expect that the simple lobes borne at the anterior lateral border of the hypopharynx in Tenthredineæ would be represented in a modified form in Lepidoptera, where they would occur at the sides of the hypopharynx behind the base of the spinneret. In this position we find the paired lobes considered by De Gryse as maxillulæ.

It, therefore, appears to me probable that the lateral lobes we have described in the mouth-floor of Tenthredinian larvæ are homologous with the maxillulæ of Lepidoptera.

Text-fig. 17.



Bibio pomonæ. Hypopharynx, dorsal aspect. The outline of the labium is indicated beneath the surface of the hypopharynx. *h.* Hypopharynx. *l.* Apical processes of labium. *m.* Maxillula. *s.* Sclerite supporting maxillula externally.

DIPTERA.

Bengtsson (2) announced the discovery of maxillæ associated with the endolabium in Tipulid *Phalacrocera*, stating that the latter structure was innervated by a pair of endolabial nerves arising from the sub-œsophageal ganglion dorsal to the mandibular nerves.

Traces of maxillulæ were sought for in the larvæ of various genera of Nemoceran diptera. These included *Chironomus*, *Tanypus*, *Bibio*, *Mycetophila*, *Tipula*, *Ptychoptera*, and *Simulium*. In the majority of cases the views of authors as to the exact limits of labium and hypopharynx were so various as to render impossible any definite conclusion as to the presence of maxillulæ associated with the latter.

In the case of *Chironomus*, however, we have the statement by Miall and Hammond (33. p. 29) that "The salivary ducts pass forwards to open above the mentum and behind a minute projection in the floor of the mouth (lingua)." When viewed from the dorsal surface the lingua (hypopharynx) of *Chironomus* sp. is seen to consist of a broad plate bearing at each side a wing-like projection which is inclined at right angles to the floor of the mouth. I have compared this condition with that found in two species of *Bibio*—*B. pomonæ* and *B. Johannis*. Specimens of the latter species were kindly given me by Mr. H. M. Morris, M.Sc., and my description refers to *B. pomonæ*. The only differences discovered between this species and *B. Johannis* with regard to the hypopharynx were those of size.

Morris (34 A. p. 96) describes the mouth-parts in his paper on the larval and pupal stages of this Nemoceran. I found that the salivary duct ran immediately dorsal to the thick bidentate structure, which is considered to be a portion of the labium. I therefore conclude that it represents the whole labium. In lateral view it appears not as a simple plate, but of composite nature. Above the end of the salivary duct is the membranous anterior portion of the mouth-floor. This has been described as the upper plate of the labium. Its position with regard to the labial duct appears to me to be conclusive evidence of the fact that it corresponds to the lingua or hypopharynx of *Chironomus*. Laterally it bears a pair of forwardly projecting pointed processes (text-fig. 17, *m.*) ·2 mm. in length .These are so disposed that together with the hypopharynx they form a membranous crescentic structure. The exterior surface is supported by the arm of a chitinous sclerite *s*. The ventral portion (*v.*) of this sclerite is associated by means of a chitinous connective with the lateral angles of the labium.

The form of the hypopharynx and its lateral projections recalls in some features that of *Ilibius*, one of the less specialised Dytiscids, which belong to the most primitive suborder of Coleoptera. Moreover, Morris (1917, p. 104) gives reasons for regarding the larva of *Bibio* as primitive amongst Diptera. Thus, if maxillulæ exist in Dipterous larvæ, we should expect to find them present in such a form as this. The suggestion is therefore put forward that further investigation may demonstrate the maxillular nature of the processes borne by the hypopharynx in the larva of *Bibio*, and of the similarly located projections in *Chironomus*.

SUMMARY OF CONCLUSIONS.

Briefly, then, the presence of maxillulæ as a pair of appendages more or less closely associated with the hypopharynx is a characteristic feature of Apterygota. They are in the least modified condition in *Machilis*. I have emphasised the great degree of reduction which they present in *Lepisma*. They are well developed in *Forficula* though partially fused with the hypopharynx. In the Ephemeridæ the maxillulæ lie between the mandibles and maxillæ, though they are articulated to the base of the hypopharynx. In larvæ of certain Perlaria Filipalpia I find structures projecting from the sides of the hypopharynx, which bear comparison with the maxillulæ of Ephemeridæ. In the section Setipalpia these appear to be represented by small setiferous convexities on the surface of the hypopharynx. My investigations do, I believe, tend to support the view that partially fused maxillulæ may be recognised in the membranous lobes associated with the hypopharynx in Psocidæ and certain Mallophaga, and that the so-called "lingual glands" are chitinizations of the ventral wall of the hypopharynx.

In the Endopterygota the presence of maxillulæ is established in four families of Coleoptera. I have described structures which I regard as possibly homologous with these appendages in Elateridæ, Staphylinidæ, Telephoridæ, Coccinellidæ, and Tenebrionidæ. Reference has been made to others of a more doubtful nature in *Doryphora* and *Otiorhynchus*.

The hypopharynx of Trichopterous larvæ bore comparison with that of Lepidoptera. On its dorsal surface were structures apparently homologous with the maxillulæ of Lepidoptera. Larvæ of *Sialis* and *Chrysopa* did not appear to possess these appendages. In the adults of species of these two genera of Neuroptera and in *Raphidia* the hypopharynx bore lateral structures which, from comparison with *Forficula*, seem to be wholly or partially maxillular in nature. Similarly located lobes, though modified in form, occur in larval Tenthredineæ.

Attention has been called to the presence of a pair of projections associated laterally with the hypopharynx of two Nemoceran Diptera, *Bibio* and *Chironomus*. It is doubtfully suggested that these are of the nature of maxillulæ.

A comparative review of the various conditions of the hypopharynx and maxillulæ of insects from the Apterygota to the most highly specialised mandibulate Pterygota, points to the existence of a tendency to modification along certain lines, as follows :—

(1) Greater association of the maxillulæ with the hypopharynx. (Compare *Lepisma* with *Machilis*, *Blatta*, and *Forficula* ; *Perlodes* with *Nemura*).

(2) Reduction in the size of the maxillulæ.

(3) In Exopterygota the formation of a compound "tongue" composed of the hypopharynx and maxillulæ carried by a forwardly produced portion of the mouth-floor, specially developed for the purpose. This is seen in an incipient condition in *Chloëon* and *Nemura*. It is well formed in *Forficula*, Blattidæ, and probably in Psocidæ.

(4) In the Endopterygota fusion of the distal portion of the mouth-floor with the labium. This occurs in the more specialised Coleoptera. Lateral fusion has taken place in the Neuropterous forms examined. The Tenthredinoæ, Trichoptera, and Lepidoptera represent consecutive stages in the formation of a spinneret, by prolongation of the intimately fused labium and hypopharynx around the opening of the labial duct.

Finally, I wish to lay emphasis on the tentative character of the "conclusions" here reached. In certain of the orders and families considered maxillulæ were not hitherto known to be present. It is hoped that subsequent investigation into the embryological development and morphology of allied forms will reveal the truth with regard to this interesting question.

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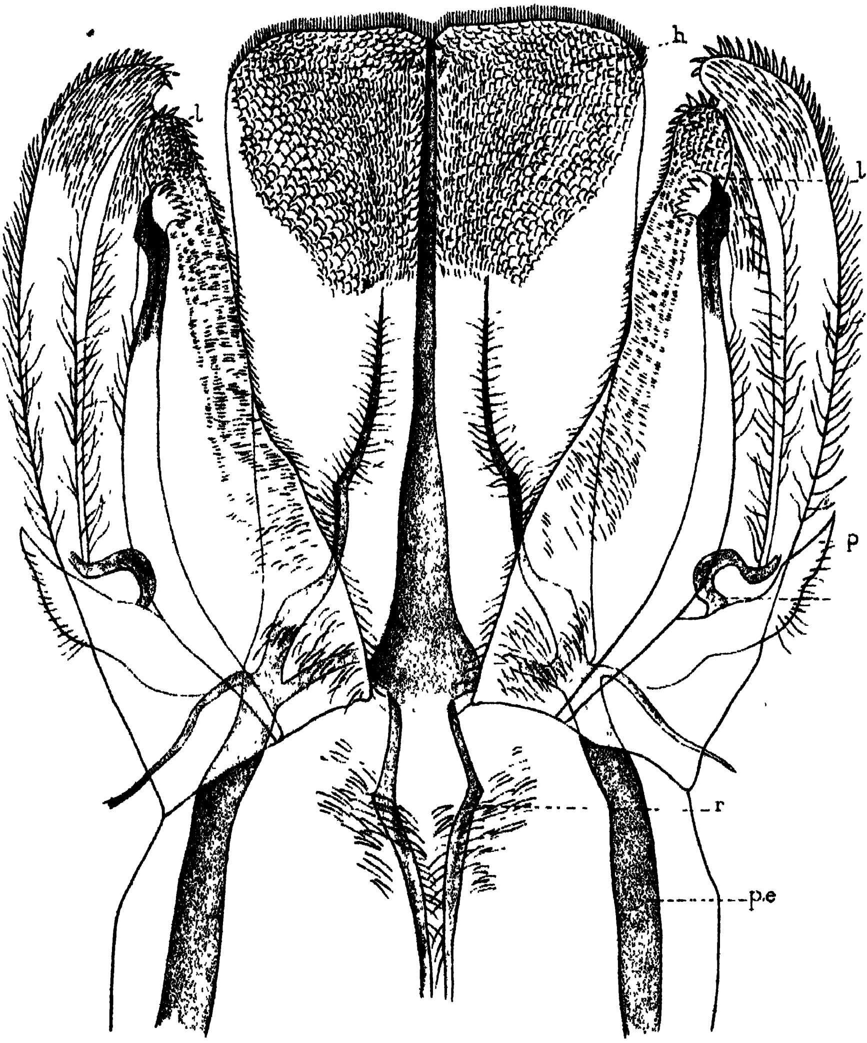
EXPLANATION OF PLATE 31.

Petrobius sp. Dorsal aspect of Hypopharynx and Maxillulæ.
From a preparation stained with acid fuchsin.

a. Indication of articulation. *h.* Hypopharynx. *l.* Inner lobe of maxillula. l_1. Comb-like projection from surface of maxillula. *m.* Left maxillula. *p.* Palp. *p.e.* Peduncles of hypopharynx. *r.* Chitinous rods in ventral pharyngeal wall.



A. M. E. del

Westwood
Bequest.

C. Hodges & Son lith

PETROBIUS sp.

The Vertebrate Fauna of Houtman's Abrolhos (Abrolhos Islands), Western Australia.

By W. B. ALEXANDER, M.A., Late Keeper of Biology in the Western Australian Museum. (Communicated by Dr. W. J. DAKIN, Professor of Zoology in the University of Liverpool.)

[Percy Sladen Trust Expedition to the Abrolhos Islands under the leadership of Prof. W. J. DAKIN.]

[Read 17th March, 1921.]

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INTRODUCTION.

THE first reference to the fauna of the Abrolhos is contained in the journal of Francis Pelsart, 1629 (1). He states that in the two or three large islands (the Wallaby Islands) there were large numbers of a "species of cats," of which he gives a very good description, the first proper account of a species of kangaroo written, though I am not sure whether it was published till 1899, as it was omitted from the popular account of his voyage published at the time. He adds that in these two islands they found a number of grey turtle-doves, but no other animals.

Capt. Wickham, in command of H.M.S. 'Beagle,' surveyed the islands in April 1840, and the officers under him made considerable collections, which are now in the British Museum—unfortunately, in most cases with nothing to indicate on which islands they were obtained. In his account of the voyage (2) Stokes mentions hair-seals seen at Pelsart Island and Rat Island, the latter obtaining its name from "the quantity of that vermin with which it was infested." The Wallaby Islands derived their name likewise from the number of those animals found on them, and Stokes remarks specially that not a single wallaby was found on North Island. On Rat Island they obtained numbers of a lizard, named *Silubosaurus stokesii* by J. E. Gray in the appendix to the volume. One of these Lieut. Emory brought alive to England. The Pigeon Islands were so named because "the common Bronze-winged Pigeon" was found there in great numbers. The burrows of the Sooty Petrel or Mutton-bird are mentioned as abundant on Rat Island and the south-west side of West Wallaby Island. Stokes remarks that the birds met with on Houtman's Abrolhos, with the exception of one resembling in shape and colour a small quail (*Hemipodius scintillans*, Gld.) numerous on North Island, were known and common on the mainland.

In 1842 Gould's collector, John Gilbert, visited the islands, and wrote a vivid account of the nesting-habits of some of the sea-birds. He also seems to have made large collections of the reptiles etc., which are now in the British Museum.

In 1889 the group was visited by Mr. A. J. Campbell, who wrote an account of the fauna (3), partly from information given him by Mr. Broadhurst, whose firm had commenced working the guano, and by Mr. Beddoes, the firm's manager on the islands.

In 1894 Mr. O. Lipfert spent three months at the Abrolhos at the invitation of Mr. Broadhurst, collecting for the Western Australian Museum. I have to thank Mr. Lipfert for lending me a manuscript list of the birds that he found nesting.

In 1897 Mr. R. Helms paid a short visit to the islands accompanied by Mr. Lipfert, and in 1902 an account of his visit was published (4). He added somewhat to the list of birds given by Campbell. In 1899 the islands were visited by Mr. R. Hall, who published a list of the birds (5), adding a few not recorded by Helms.

In 1907 the Abrolhos Islands were visited by a party, amongst whom were Messrs. Milligan, Conigrave, and Gibson. The last wrote an account of the birds met with (6). Specimens obtained by Milligan and Conigrave are in the W. A. Museum.

I visited the islands with Prof. Dakin in November 1913, with funds provided by the Percy Sladen Trust, and, where not otherwise mentioned, the observations hereafter recorded were made on that visit *. Mr. J. McMillan, who accompanied us, gave valuable assistance on this expedition.

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* [This was the first Percy Sladen Trust expedition to the Abrolhos Islands, the second was made in 1915.—W. J. D.]

SECTION 1.—The Land Vertebrates.

MAMMALIA.

Rodentia. MURIDÆ.

EPIMYS FUSCIPES (*Waterhouse*) (not Gould). Dusky-footed Rat.

Two examples of this species, obtained in November 1907, are in the Western Australian Museum. They were caught on the sand-hills on East Wallaby Island, the only locality in which we met with the species.

The Abrolhos specimens are decidedly smaller than those in the W.A. Museum from other localities, and their skulls are narrower in proportion to their length. As the teeth are only slightly worn, it is probable that both specimens are young, and these differences may be due to age. When a longer series is available, it may be necessary to create a subspecies for them.

Marsupialia. MACROPODIDÆ.

MACROPUS EUGENII HOUTMANNI (*Gould*). Dama Wallaby or Tammer.

As already mentioned, this wallaby was first met with by Pelsart in 1629 on "two or three of the larger islands." The types of *Macropus houtmanni*, Gould, were obtained by the naturalists of the 'Beagle' in 1840 on East and West Wallaby Islands, the only islands on which they are found, and are in the British Museum, together with specimens obtained by Gilbert. In 1888 Oldfield Thomas wrote (7): "I have come to the conclusion that it is impossible to admit more than a single western species, notwithstanding the very striking differences that exist between the individuals long isolated in the islands of the Houtman's Abrolhos and those living on the mainland. The differences fade away on the examination of a large series, and specimens from the small islets close to the coast are as a rule more or less intermediate."

Since 1888 the general use of trinomials to designate differences of this nature leads me to suppose that Mr. Thomas would now adopt the nomenclature I am using, especially when it is borne in mind that the small islands to which he refers as inhabited by intermediate forms are not geographically intermediate, but lie off the south coast of Australia at the opposite extremity of the range of the species on the mainland.

The animals are very plentiful on the two islands which they inhabit, chiefly amongst the coastal sand-hills and on the portions of the islands where the limestone rock outcrops. These are the only regions where the bushes are large enough to afford them cover during the daytime, which they appear to spend in the shade, only coming out at night.

Introduced Mammals.

Stokes found great numbers of rats on Rat Island, but it is not clear whether these were *Rattus* (*Epimys*) *fuscipes* or *R. rattus* or *R. norvegicus*. If they were from the latter they were presumably the result of one of the numerous shipwrecks which occurred on the islands from 1629 onwards. Rats are stated also to have occurred on Pelsart Island, but we did not meet with them on either of these islands. Rabbits also were formerly found on Pelsart Island. though there is no evidence as to how they got there.

Unfortunately, the domestic cat has been introduced. We saw an individual on Rat Island and the tracks of one on Pelsart Island, and this probably accounts for the disappearance of the rodents, as well as the larger lizards, on these groups. It is to be hoped that they will not reach the Wallaby Group.

REPTILIA.

Ophidia. BOIDÆ.

PYTHON SPILOTES VARIEGATUS (*Gray*). Carpet-Snake. Plentiful on West Wallaby Island. The largest individual we met with was about 7 ft. in length.

COLUBRIDÆ.

DENISONIA CORONATA (*Schleg.*). Crowned Whip-Snake. The British Museum has a specimen obtained by Gilbert. A small grey snake seen by me on East Wallaby Island, but unfortunately not captured, was probably of this species.

RHYNCHELAPS BERTHOLDI (*Jan*). Ringed Snake. Mr. Lipfert obtained a specimen of this species on West Wallaby Island in 1895. A large example obtained by the guano-workers was forwarded to Prof. Dakin in 1915, and is now in the W.A Museum.

Lacertilia. GECKONIDÆ.

GYMNODACTYLUS MILIUSII (*Bory*). Flat-tailed Gecko. Frequent on West Wallaby Island ; also found on Pigeon Island.

HETERONOTA BYNOEI (*Gray*). The types of this species, in the British Museum, were obtained on Houtman's Abrolhos.

PHYLLODACTYLUS MARMORATUS (*Gray*). The types, in the British Museum, are from the Abrolhos.

PHYLLODACTYLUS OCELLATUS (*Gray*). The types of *P. bilineatus*, Gray, regarded by Boulenger as a synonym of this species, were obtained on the Abrolhos.

DIPLODACTYLUS SPINIGERUS, *Gray*. The types, in the British Museum, are from the Abrolhos. We obtained two specimens on West Wallaby Island.

DIPLODACTYLUS VITTATUS, *Gray*. The types of *D. ornatus*, Gray, regarded by Boulenger as a synonym of this species, were collected on Houtman's Abrolhos.

PEROPUS VARIEGATUS (*Dum. & Bibr.*). A specimen in the British Museum is from Houtman's Abrolhos.

PYGOPODIDÆ.

DELMA FRASERI, *Gray*. Fraser's Slow-worm. We met with two individuals of this species on West Wallaby Island.

LIALIS BURTONIS, *Gray*. Burton's Slow-worm. The British Museum has a specimen from Houtman's Abrolhos. We met with one example on West Wallaby Island.

AGAMIDÆ.

AMPHIBOLURUS BARBATUS (*Cuv.*). Jew Lizard. Plentiful on East and West Wallaby Islands and North Island, especially amongst the sand-hills. Often observed in the bushes a couple of feet from the ground.

SCINCIDÆ.

EGERNIA WHITEI (*Lacep.*). The British Museum has a specimen from the Abrolhos.

EGERNIA KINGI (*Gray*). Common on West Wallaby Island, chiefly in the region covered by flat slabs of limestone, under which it lurks during the daytime. Also met with on East Wallaby Island and the Pigeon Islands.

EGERNIA STOKESI (*Gray*). Very plentiful wherever there are loose rocks on the East and West Wallaby Islands and Pigeon Islands. Sometimes as many as four or five individuals will be found by turning over a single stone. At the time of Stokes's visit it was evidently common on Rat Island, and Campbell also met with it there in 1889. I think that it has probably been destroyed on that island by the introduction of cats.

TRACHYSAURUS RUGOSUS, *Gray*. Stump-tailed Lizard. The British Museum has a specimen from Houtman's Abrolhos.

LYGOSOMA LESUEURI, *Dum. & Bibr.* The British Museum has a specimen obtained on the Abrolhos.

LYGOSOMA RICHARDSONI (*Gray*). The type, in the British Museum, is from the Abrolhos.

LYGOSOMA QUADRILINEATUM (*Dum. & Bibr.*). The British Museum has a specimen from the Abrolhos.

LYGOSOMA sp. A small species with an orange head and pink throat was very common in sandy localities on the Wallaby Islands. A specimen which I obtained is in the W.A. Museum, and appears to belong to a new species, but I hope to obtain further specimens. The small lizards of this genus are so active that they are very difficult to obtain, and several other species probably occur. A small form which lives among the scrub was seen on Long Island and Sandy Island in the Wallaby Group, as well as on Rat Island and Pelsart Island. A rather larger species was also observed on Rat Island.

LYGOSOMA PRÆPEDITUM, *Blngr.*, is recorded by Campbell.

AMPHIBIA.

Anura.

CYSTIGNATHIDÆ.

LYMNODYNASTES DORSALIS (*Gray*). Specimens from Houtman's Abrolhos are in the British Museum.

BUFONIDÆ.

MYOBATRACHUS GOULDI (*Gray*). Specimens from the Abrolhos are in the British Museum.

We did not see any Amphibia, but on Pigeon Island and Long Island we heard sounds after dark which sounded like those made by some species of frog. Considerable search with a lantern on Pigeon Island failed to reveal the animals from which these noises emanated.

LAND-BIRDS.

Turniciformes.

TURNICIDÆ.

ORTYGODES VARIUS SCINTILLANS (*Gould*). Painted Quail.

Common on East and West Wallaby Islands, one of the Pigeon Islands, and North Island. At the time of our visit in November 1913 the breeding-season seemed to be practically over, as young birds were met with which could fly almost as strongly as the adults.

The Abrolhos birds were described by Gould (P. Z. S. 1845, p. 62) as a distinct species, "*Hemipodius scintillans*," described as "very nearly allied to but much smaller than *H. varius*." In the 'Birds of Australia' Gould writes that the species "much resembles *H. varius*, but is little more than half the size of that species; independently of which the colouring is much lighter, more varied and sparkling, the white margins of the back feathers more numerous and conspicuous, and the markings of the throat and breast of a crescentic instead of an elongated form."

In 1911 Mathews (8) separated the form of *Turnix varia* found in South-West Australia as *T. varia stirlingi*, writing that it "agrees with *T. varia scintillans* in its darker upper coloration but differs in its much paler under-surface and more white on the ear-coverts."

In 1913 the same writer (9) placed his own *T. varia stirlingi* as a synonym of *T. varia scintillans*, Gould.

As Mr. Mathews informed me that he had not examined any birds from the Abrolhos, I presume he was relying on Gould's description in taking this action. There are two Abrolhos birds in the Western Australian Museum obtained in 1894, and in my opinion they are quite sufficiently different from birds from the mainland as to need a subspecific name. They are much lighter in colour than all the birds from the mainland, for which I will use Mathews's name of *T. varia stirlingi.* Now, though Gould's figure shows *scintillans* as "darker" than *varius*, in the description he says it is "lighter." In the second place, the white patch on the throat extends further down, and the white markings on the breast are fairly narrow, only widening a little towards the tip instead of being crescentic as in *stirlingi.* I cannot help thinking that Gould meant to write that they were "of an elongated instead of a crescentic form," instead of the exact opposite. In addition, both the specimens of *scintillans* have far more white spots on the cheeks and head than any of the specimens of *stirlingi*, in none of which do they extend right across the back of the head; moreover, these spots and the streaks on the breast are white instead of buffish, which I presume is what Gould referred to when he said the colouring was "more varied and sparkling." Other slight differences noticed are that the black patches on the back are distinctly more broken up by cross-bars in *scintillans*, the reddish colour on the sides of the breast extends much further down, and, as noted by Gould, "the white margins of the back feathers are more numerous and conspicuous."

In making these comparisons I have had before me the two specimens of *Ortygodes varius scintillans* from the Abrolhos, seven specimens of *O. varius stirlingi* from localities from Perth to Denmark, W.A., and one specimen of *O. varius varius* from Queensland.

Columbiformes.

COLUMBIDÆ.

COSMOPELIA ELEGANS NEGLECTA, *Mathews.* Brush Bronze-wing Pigeon.

Plentiful on East and West Wallaby Islands and North Island, though, curiously enough, we did not meet with them on the Pigeon Islands, which Stokes named from their abundance there. A nest containing one fresh egg was found by me on East Wallaby Island in November 1913, and Hall captured a young bird that had just left the nest on Pigeon Island in November 1899. "Grey Turtle-Doves" were seen by Pelsart on the Wallaby Islands in 1629. Stokes recorded them as the "Common Bronze-winged Pigeon" and Campbell as *Phaps chalcoptera.* Owing to their rapid flight and their habit of flying just over the bushes and then ducking down again, it is by no means easy to get a good view of them, and perhaps Campbell did not secure a specimen. There are two specimens from the Abrolhos in the W.A. Museum, obtained in 1894, and I cannot discover any differences between them and specimens from the mainland, though they are both distinctly below the average in size.

Ralliformes.

RALLIDÆ.

HYPOTÆNIDIA PHILIPPENSIS (*Linn.*). Buff-banded Rail.

Campbell saw this species on Rat and Pelsart Islands, and states that it is known to breed on the latter. We did not meet with the species. Birds from this locality would presumably be *H. p. mellori*, Mathews.

PORZANOIDEA PLUMBEA ROBERTI, *Mathews.* Spotless Crake.

Campbell states that this species occurs on Pelsart Island, "about the mangrove swamp" (there are numerous mangrove swamps on the island). Gibson saw a pair in November 1907, "on a rocky islet forming part of Rat Island." "This record for these birds," he very justly adds, "is, I think, somewhat unique." Judging from the localities it frequents on the mainland, this is one of the most unlikely birds one could think of to be found on these dry islands.

Falconiformes.

FALCONIDÆ.

CERCHNEIS CENCHROIDES UNICOLOR (*Milligan*). Nankeen Kestrel.

A bird of this species was seen on West Wallaby Island, and two days later another, or more probably the same individual, on North Island. Doubtless it was only a visitor from the mainland.

Coraciiformes.

ALCEDINIDÆ.

SAUROPATIS SANCTA WESTRALASIANA (*Campbell*). Sacred Kingfisher.

Hall found a pair frequenting an abandoned jetty at Pelsart Island, going in and out among the planking as if nesting. He shot the female.

Passeriformes.

HIRUNDINIDÆ.

HIRUNDO NEOXENA CARTERI, *Mathews*. Welcome Swallow.

Met with on almost every island. The birds appear to nest under the overhanging shelves or low cliffs found round most of the islands. On Pigeon Island a swallow was seen to carry nesting-material into a situation of this kind.

MUSCICAPIDÆ.

WHITEORNIS GOODENOVII RUFICAPILLUS, *Mathews*. Red-capped Robin.

Hall shot a young bird of this species on Pelsart Island, which he considered, doubtless correctly, as a stray visitor from the mainland.

TIMELIIDÆ.

PTENŒDUS MATHEWSI MATHEWSI (*Iredale*). Rufous Song-Lark.

Hall met with three birds of this species on Pelsart Island in the mangroves and shot one of them, a young male. He thought they might have nested on the island, but probably they were only visitors from the mainland.

SYLVIIDÆ.

SERICORNIS MACULATUS FUSCIPES, subsp. nov. Spotted Scrub-Wren.

Common amongst the bushes on East and West Wallaby Islands. In the 'Birds of Australia' Gould, after referring to the variability of *S. maculatus*, states that specimens from Houtman's Abrolhos differ from examples from the mainland in their rather smaller size, much greyer tint on the back, and much darker-coloured legs. In the Western Australian Museum are four rather poor specimens from the Abrolhos obtained by Milligan in November 1907. I have compared these with 16 specimens from various localities in S.W. Australia, including two from Albany, the type-locality of *S. maculatus*. There are also available four specimens from the islands in Sharks Bay, one of them from Bernier Island, the type-locality of *S. baltoni*, Grant, and the other three, which agree closely with it, from Dorré Island.

None of the specimens agrees with *S. mathewsi warreni*, Mathews, which is said to have a "greenish (not greyish) olive back," though there are examples from localities on both sides of the Warren River.

Specimens from the Abrolhos appear to be nearer to *S. mathewsi balstoni* than to typical *S. mathewsi maculatus*; they differ from both, however, in their very dark legs, as noticed by Gould. I am therefore using a new name for birds from these islands. They have much less of the rufous tinge on the rump than in *S. mathewsi maculatus*, and rather less than in *S. mathewsi balstoni*. The dark streaks on the throat are narrower than in *maculatus*, but rather larger than in *balstoni*. The size is almost the same as *balstoni*, distinctly smaller than *maculatus*. Mr. Lipfert found a nest of this bird on West Wallaby Island on December 2, 1894.

ZOSTEROPIDÆ.

ZOSTEROPS GOULDI, *Bonap.* Green-backed White-eye.

Noticed in small flocks or family-parties on almost every island or islet visited. They seem to have a special liking for mangroves. On several occasions they were seen flying from one islet to another. Mr. Lipfert found a nest containing one egg on Rat Island on November 23, 1894.

MOTACILLIDÆ.

ANTHUS AUSTRALIS, *Vieillot.* Australian Pipit.

Helms obtained one of these birds on Gun Island. We met with a pair on North Island. No doubt they are only visitors from the mainland, and probably they belong to the subspecies *A. a. bilbali*, Mathews.

SUMMARY.

MAMMALS.—The two indigenous species of Mammals are only found in the Wallaby Group, the Wallaby on both the large islands, the Rat, as far as is known, only on East Wallaby Island. The latter is probably, and the former certainly, subspecifically distinct from the mainland species.

SNAKES.—The three species of snakes do not appear to differ from the mainland forms. At present two have been found only on West Wallaby Island and the third on East Wallaby Island.

LIZARDS.—Four families are represented by some 19 species. The seven species of Geckonidæ are only known from the Wallaby Group, the two species of Pygopodidæ only from West Wallaby Island, and the single species of Agamidæ from the Wallaby Islands and North Island. The Scincidæ are represented throughout the group, though we only met with the smaller species of *Lygosoma* outside the Wallaby Group; one of the larger forms, *Egernia stokesi*, was, however, formerly plentiful on Rat Island.

FROGS.—Nothing is known as to the habitat of the two species recorded from the group.

BIRDS.—Of the 12 land-birds recorded from the Abrolhos, four (Kestrel, Robin, Song-Lark, and Pipit) are certainly only casual visitors, five others (Rail, Crake, Kingfisher, Swallow, and White-eye) are probably visitors from the mainland, though all but the Crake and Kingfisher have been known to breed ; the remaining three are almost certainly residents.

Of these, the Pigeon and the Quail are found in the Wallaby Group and on North Island, the Scrub-Wren only on the Wallaby Islands. The two latter are subspecifically distinct from the mainland forms.

Looking now at the different groups of islands we find that *West Wallaby Island* has two snakes and two slow-worms confined to it, *East Wallaby Island* has one snake and one rat confined to it, whilst the two *Wallaby Islands* possess subspecies of a wallaby and a bird peculiar to them.

The *Wallaby Islands*, with *North Island*, possess also one lizard and two birds not found in the other groups, one of the birds being a subspecies peculiar to the group.

This distribution strongly suggests that the whole land-fauna of the group has been derived from the Wallaby Islands *. One of the chief features of the weather on the Abrolhos is the prevalence during the summer of "southerly busters," extremely strong southerly winds. The presence of the two birds on North Island is thus easily accounted for, and it is noteworthy that the one lizard which habitually climbs bushes is the one which has managed to reach that island. Doubtless at times the bushes on the sand-hills which it frequents are blown into the sea, and occasionally reach North Island.

The fact that the smaller skinks are found on many of the small sandy islets seems to show that the sea is no great barrier to their distribution. Probably their eggs are not damaged by floating in sea-water for some time. The larger Spiny-tailed Skink, *Egernia stokesi*, is a favourite food of the Sea-Eagles, and it is possible that individuals may be captured by them on the Wallaby Group and carried to Rat Island, and if one occasionally escaped this would account for their presence on that group.

A striking feature of the Abrolhos land-fauna is its southern character. Our knowledge of the distribution of animals in Western Australia is perhaps not sufficient to allow us to be dogmatic on the point, but there is every indication that when the islands were peopled from the mainland the fauna of the Geraldton district must have approximated much more than it does now to that of the extreme south-west. The range of *Macropus eugenii* does not now extend much north of Perth, whilst *Epimys fuscipes* is only known from the south coast and the islands of the Recherche Archipelago. *Ortygodes varius* and *Cosmopelia elegans* are not recorded from farther north than the Moore River, though it is not improbable that they may occur ; *Porzanoidea plumbea* is not recorded from north of Perth.

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* [A discussion on the origin of the fauna of the Abrolhos Islands will be given in the concluding paper of the series.—W. J. DAKIN.]

The most northerly record that I know for *Denisonia coronata* and for *Egernia whitei*, "Perth," is less than 30 miles north of Perth. *Lygosoma richardsoni* is known only from the Abrolhos. The remainder of the species are found farther north on the mainland, but there is not one of them which is not found in the south-west.

Section 2.—**The Marine Vertebrates.**

SEA-BIRDS.

Sphenisciformes.

SPHENISCIDÆ.

EUDYPTULA MINOR WOODWARDI, *Mathews.* Little Penguin.

Recorded by Hall without further particulars. I know of no other record of its occurrence north of Fremantle, and consider the record needs confirmation.

Procellariiformes.

HYDROBATIDÆ.

PELAGODROMA MARINA DULCIÆ, *Mathews.* White-faced Storm-Petrel.

Gilbert met with this species on a small island about three miles south of East Wallaby Island. The young birds were almost ready to leave their holes in January. Campbell found them nesting on Beacon Island; the burrows contained young about 10 days old on December 15th. Lipfert found eggs on a sand-patch off Wooded Island in November 1894; and Hall obtained eggs and nestlings, on West Wallaby Island and South Island, Pelsart Group, in November 1899

PROCELLARIIDÆ.

PUFFINUS ASSIMILIS TUNNEYI, *Mathews.* Allied Shearwater.

Campbell obtained a specimen of this bird at Rat Island, and Gibson noted them at several islands, principally on Wooded Island, where he obtained numerous almost full-grown young in the burrows (November 1907). Hall states that the eggs have been found on Pelsart Group in July. We saw them several times about West Wallaby Island. One individual was found sitting on the water in the daytime, others flying about at night, when, like the Mutton-birds, they seemed to be attracted by the lights of the ship. They are not nearly so abundant as the next species.

THYELLODROMA PACIFICA CHLORORHYNCHA (*Lesson*). Wedge-tailed Shearwater or Mutton-bird.

All those who have written about the Abrolhos have referred to the great numbers of these birds. During the daytime they are to be seen flying over the sea in the neighbourhood of the islands in small or large flocks. We saw them on one occasion in pursuit of a shoal of fish, on which Roseate Terns, Dolphins, and Bonetas were also levying toll. Unlike the Terns, which dive straight down, the Mutton-birds first settle on the water and then plunge under, apparently with the assistance of their wings. When rising from the water the wings are half-spread, but not flapped, and the bird gets up the velocity required to start it in flight by paddling along the surface with its feet.

On the islands they appear from their burrows in great numbers as soon as it is dark, uttering the most weird and mournful cries. They are unable to stand on the ground, or to walk, so that they are obliged to use their wings, by whose aid they shuffle about among the bushes in a most awkward manner and are readily captured. They seem to be attracted by a light, as they often flew round the ship in the evening and once or twice came on board.

On many of the islands, especially West Wallaby Island and the southern end of Pelsart Island, their burrows are so numerous that when walking over the areas inhabited by them one sinks in, almost up to the knees, at every step. Their burrows were also seen on Rat Island, Long Island, and one of the Pigeon Islands. Fresh eggs were found in them on Pelsart Island, and Mr. Lipfert obtained them on Gun Island.

During one moonlight night I spent some time watching a Mutton-bird excavating a burrow in the sand. It used its feet alternately, throwing out an almost continuous stream of sand behind it to a distance of about a yard. The burrows when completed extend to a distance of two or three feet into the ground at an angle.

It strikes one as very remarkable that though the legs of these birds are not strong enough to support the weight of their body, yet they can be used for shovelling away sand continuously, apparently for hours. Moreover, they can use them as paddles on the water sufficiently rapidly to raise themselves from the surface when about to fly.

MACRONECTES GIGANTEUS ALBUS (*Potts*). Giant Petrel.

A specimen in the W.A. Museum was obtained at the Abrolhos in 1894. Campbell states (**10**), on the authority of Beddoes, that they visit the islands every winter, which is not improbable, as they occur off Fremantle every year during that season. The subspecific name which Mathews uses for the New Zealand and Australian form is singularly unfortunate, as, so far as I am aware, every specimen obtained in Western Australia has been completely dark in plumage without a single white feather. There are six specimens in the W.A. Museum, and I have seen remains of several others washed up on the beach.

DIOMEDEIDÆ.

NEALBATRUS CHLORORHYNCHUS CARTERI (*Rothschild*). Yellow-nosed Mollymawk.

A skull obtained on Pelsart Island in 1894 is in the W.A. Museum. When on the unfortunate Federal trawling ship 'Endeavour,' in June 1912, I found these birds numerous in the neighbourhood of the Abrolhos.

Lariformes.

LARIDÆ.

HYDROPROGNE TSCHEGRAVA STRENUA (*Gould*). Caspian Tern.

These birds occur in pairs or in small colonies on nearly all the islands, often nesting in company with other species. We found eggs or young birds on West Wallaby Island, one of the Pigeon Islands, Long Island, Wooded Island, and Pelsart Island. In most cases young birds were more numerous than eggs, and some of the young were almost fledged. Mr. Mathews, in the 'Birds of Australia,' states that the Australian form of Caspian Tern never nests in colonies, but on Wooded Island I counted eight nests close together, whilst, judging by the number of old birds, there was a larger colony at one spot on Pelsart Island. Hall reported a colony of some 13 pairs nesting on West Wallaby Island in 1899.

THALASSEUS BERGII (*Lichtenstein*). Crested Tern.

Distributed throughout the islands. Breeding colonies were met with on West Wallaby Island, Wooded Island, and Pelsart Island. The young birds were much more numerous than the eggs, and many of them were almost fully fledged. There are two specimens in the W.A. Museum from the Abrolhos, but I have been unable to decide whether they should be referred to *T. bergii pelecanoides* (King) or *T. bergii gwendolenæ*, Mathews. They do not appear to differ in size from birds from Barrow Island and Bedout Island, which would be the former according to Mathews, but they are also similar to birds from the neighbourhood of Perth, the type-locality of the latter. The only specimen in the W.A. Museum, which is decidedly larger than any of the others, is one from Esperance on the south coast.

STERNA DOUGALLI GRACILIS (*Gould*). Roseate Tern.

These birds were met with in large flocks sitting on the reefs on North Island, East Wallaby Island, Long Island, Rat Island, Wooded Island, and Pelsart Island. We did not find them nesting until the last day of our visit, when we found a considerable colony on the north end of Pelsart Island which had just begun to lay on the piles of coral fragments. Campbell also found them nesting on Pelsart Island.

[STERNULA ALBIFRONS TORMENTI (*Mathews*). White-shafted Ternlet.

Campbell states that he saw a pair of these birds near Rat Island in company with Little and Caspian Terns. He obtained a skin, but appears to be doubtful whether it may not be a young *S. nereis.* The record needs confirmation, as there is no other record of this species from the southern half of the western coast of Australia.]

STERNULA NEREIS HORNI (*Mathews*). White-faced Ternlet.

These little birds were seen on practically every island visited, and from their behaviour it seems probable that isolated pairs, or a few pairs together, nest on nearly all the sandy beaches or heaps of dead coral. We only found nests on the east side of West Wallaby Island, where there was a colony of several hundred individuals. The eggs were fresh or very slightly incubated, one, two, or three being the numbers found in a nest. Campbell, Lipfert, and Gibson all found colonies nesting on Pelsart Island.

ONYCHOPRION FUSCATA SERRATA (*Wagler*). Sooty Tern.

There can be no doubt that this is the most plentiful bird found on the Abrolhos at the present time during the nesting season. On Rat Island their numbers are prodigious, they nest under almost every bush and in many places also amongst the herbage; there is also a very large colony on the south end of Pelsart Island and another on Wooded Island. In the Wallaby Group they are not found on the Wallaby Islands, nor on North Island, but there are great numbers on all the smaller islands, the Pigeon Islands, Long Island, and Pelican Island. On Rat Island, Wooded Island, and Pelsart Island most of them had eggs at the time of our visit, though a fair number of young birds had already been hatched, but, curiously enough, those in the Wallaby Group had scarcely begun nesting, as only one egg was found—on Long Island.

MELANOSTERNA ANÆTHETUS NOVÆHOLLANDIÆ (*Stephens*). Bridled Tern.

We only met with a single pair of this species on a small islet off Rat Island, and did not find a nest. Gilbert and Campbell both found them breeding in small numbers, but do not state on which island or islands. Lipfert and Gibson found a few nests on Pelsart Island. There is no doubt that this is the rarest of the Laridæ which nest in the Archipelago.

ANOUS STOLIDUS GILBERTI, *Mathews.* Noddy Tern.

This species nests in very large numbers on Rat Island and the south end of Pelsart Island, whilst there is a smaller colony on Wooded Island. In each case their colonies occur amongst those of the Sooty Tern, most of the nests being built on the bushes, though in many cases they are flat on the ground; these latter appear to be those of birds which have failed to obtain a site on the top of the bushes within the limits of the colony, and, rather than utilise bushes only a few yards away from the rest of their species, they are content to take up a position on the ground. At the time of our visit the majority of the nests contained eggs, though many young birds had already been hatched. All previous writers on the group have referred to the absurd tameness of the Noddies: they have to be lifted from the nest in order to see what it contains, though this has to be done with caution as they give vicious pecks with their beaks. Many of them undoubtedly fall victims to the cats, and were it not that these latter are kept down by the difficulty of finding food at other seasons of the year, when they appear to feed chiefly on crabs, it would doubtless not be long before the Noddies were exterminated. As it is, their numbers are only exceeded by those of the Sooty Terns.

MEGALOPTERUS TENUIROSTRIS MELANOPS (*Gould*). Lesser Noddy.

These birds were discovered on Pelsart Island by Gilbert in 1842, though Stokes had previously observed their curious nests. Gilbert's remarkably vivid account of their numbers and nesting-habits, first read by Gould at the meeting of the Zoological Society on February 27, 1844, and published in the P. Z. S. for that year, has been quoted by every writer who has since dealt with this subspecies, for the colony on the Abrolhos is still its only known breeding-place. The following quotations give an idea of the number of birds at the time of Gilbert's visit. He wrote:—"I have seen many vast flocks of birds, but I must confess I was not at all prepared for the surprise I experienced in witnessing the amazing clouds (literally speaking) which these birds present when congregating in the evening . . . . even Audubon, who has been so accustomed to see such vast flocks of the passenger pigeon, could hardly avoid expressing surprise if he had an opportunity of seeing these birds at sunset, moving in one immense mass over and around their roosting-place; while the noise of the old birds' quack and the piping whistle of the young ones is almost deafening." I regret to have to record that these great flights, like those of the passenger pigeon, are now a thing of the past. Campbell wrote in 1890:—"Now that a successful guano depôt has been established upon Pelsart Island, no doubt in time the limited supply of mangrove trees will be used for fuel. What then will become of the extraordinary flights of the Lesser Noddies as they go to and from their fishing grounds? I trust the photographs I took will not soon be the 'light of other days.'" Mr. Lipfert tells me that when he visited the Abrolhos five years later, in 1894, the birds were still nesting on Pelsart Island, as they were also at the time of his visit with Helms in 1897. Hall also found them there in 1899.

On Gibson's visit in 1907 they were only found on Wooded Island, so that some time during the intervening eight years the whole colony moved from one group to another. It is a great pity that it is not known how this exodus took place, nor for certain what was its cause. The cutting down of the mangroves, suggested by Campbell, has not taken place, as I believe they only furnish very inferior timber for burning. Prof. Dakin tells me that some years ago the soil of the mangrove swamp was dug out from the roots of the trees, being almost pure guano, and probably this disturbed the birds so much that they removed to their new home.

Wooded Island, in spite of its name, has not so many mangroves as Pelsart Island, and almost every tree is covered by their nests. Their numbers at the present time, however, cannot be anything like what they were 30 years ago, as they are certainly far fewer than either the Sooty Terns or the Noddies. Moreover, there is every reason to fear that they are still decreasing, for every occupied nest on the trees there are several old ones, and Prof. Dakin tells me that on his last visit, in 1915, he thought there were fewer nests occupied than when I was with him in 1913. I can suggest no reason for this decline; there are no obvious enemies of these birds on Wooded Island, but it appears that the guano accumulated below their nests on Wooded Island is likely to be worked before long, when presumably they will have to make another move. This could not have been long delayed in any case, as the accumulation of the guano round the roots of the mangroves is rapidly killing the trees, and it is unlikely that the birds would continue to nest on the boughs of the dead trees. It is to be hoped that a change to another island may lead to an increase in their numbers, otherwise I fear they must be regarded as the last remnant of a dwindling race.

BRUCHIGAVIA NOVÆHOLLANDIÆ LONGIROSTRIS (*Masters*). Silver Gull.

These birds occur throughout the group. Small colonies were found nesting on West Wallaby Island, an islet off Rat Island, Wooded Island, and Pelsart Island. A few eggs were still not hatched, and young birds were met with in every stage from newly hatched to fully fledged.

GABIANUS PACIFICUS GEORGII (*King*). Pacific Gull.

Not so plentiful as the Silver Gull, but distributed over all the islands. No eggs were found, but young birds half-grown or fully fledged were noted on West Wallaby Island, Long Island, Wooded Island, and Pelsart Island. Mr. Lipfert found fresh eggs on an island off Rat Island on October 7, 1894.

Charadriiformes.

ARENARIIDÆ.

ARENARIA INTERPRES OAHUENSIS (*Bloxham*). Turnstone.

A very common summer visitor, found round the shore on all the islands.

HÆMATOPODIDÆ.

HÆMATOPUS OSTRALEGUS PICATUS (*King*). Pied Oyster-catcher.

Small parties of this species, or in some cases only single pairs, were seen on North Island, East and West Wallaby Islands, the Pigeon Islands, and Pelsart Island. On the latter they were several times met with on the ridges of broken coral in the centre of the island, suggesting that they were nesting there, but no nests were found. The two specimens from the Abrolhos in the W.A. Museum are referable to the northern race *picatus*.

HÆMATOPUS NIGER BERNIERI (*Mathews*). Black Oyster-catcher.

These birds were seen on the reefs at North Island, West Wallaby Island, Wooded Island, and Pelsart Island. They were not quite so numerous as the preceding species, with which they often associated. Mr. Lipfert found a nest containing one fresh egg on November 24, 1894.

CHARADRIIDÆ.

SQUATAROLA SQUATAROLA HYPOMELAS (*Pallas*). Grey Plover.

A specimen in the W.A. Museum was obtained on the Abrolhos in the summer of 1894. We saw a flock of birds, either of this species or Golden Plovers, on the shore of West Wallaby Island.

LEUCOPOLIUS RUFICAPILLUS TORMENTI (*Mathews*). Red-capped Dotterel.

Very abundant on the sandy shores of North Island and East and West Wallaby Islands, but not met with in the southern groups, where sandy beaches are unusual. Breeding was apparently over, or nearly so, as young birds were often seen with the adults on the beaches, but on West Wallaby Island pairs of birds were met with on the sandy flats in the interior of the island as if nesting.

SCOLOPACIDÆ.

NUMENIUS CYANOPUS, *Vieillot*. Australian Curlew.

Campbell met with this species in the Wallaby Group in the summer of 1889.

PHÆOPUS PHÆOPUS VARIEGATUS (*Scopoli*). Whimbrel.

Campbell records that he saw a small flock at "the mangrove swamp" on Pelsart Island on December 23, 1889.

VETOLA LAPPONICA BAUERI (*Naumann*). Barred-rumped Godwit.

Lipfert shot a specimen on Gun Island in the summer of 1894.

HETEROSCELUS INCANUS BREVIPES (*Vieillot*). Grey-rumped Sandpiper.

A specimen in the W.A. Museum was obtained on the Abrolhos by Lipfert in the summer of 1894.

ACTITIS HYPOLEUCUS AURITUS (*Latham*). Common Sandpiper.

A specimen in the W.A. Museum was obtained on the Abrolhos by Lipfert in the summer of 1894.

GLOTTIS NEBULARIUS GLOTTOIDES (*Vigors*). Greenshank.

A specimen in the W.A. Museum was obtained on the Abrolhos by Lipfert in the summer of 1894.

PISOBIA MINUTA RUFICOLLIS (*Pallas*). Little Stint.

Frequent, especially about the Wallaby Islands. Recorded by Gilbert and Campbell. Four specimens shot by Lipfert in the summer of 1894 are in the W.A. Museum.

EROLIA FERRUGINEA CHINENSIS (*Gray*). Curlew-Sandpiper.

Seen on the shores of West Wallaby Island. Recorded by Campbell. A specimen from the Abrolhos is in the W.A. Museum.

ANTELIOTRINGA TENUIROSTRIS (*Horsfield*). Great Knot.

A specimen obtained by Lipfert on the Abrolhos in the summer of 1894 is in the W.A. Museum.

No doubt this list of wading birds would be enlarged by further collecting, as several other species commonly found in South-West Australia during the summer must visit the Abrolhos at times.

Ardeiformes.

ARDEIDÆ.

DEMIGRETTA SACRA COOKTOWNI, *Mathews*. Reef-Heron.

Seen on the reefs at North Island, one of the Pigeon Islands, Rat Island, Wooded Island, and Pelsart Island. Two nests were found on Wooded Island, in both cases situated on a ledge of rock behind a bush under an overhanging cliff at the edge of a lagoon. One nest was empty, the other contained two fresh eggs. All the birds were blue, except one of a pair seen flying together at North Island which was white. To my mind the evidence points to these two forms being an example of dimorphism within the species, and I am therefore using the well-known name of *sacra* for the species. It was rejected by Mathews as having been applied to an intermediate form which he regards as a hybrid, but whether the two forms are distinct species or not, I think the evidence is clear that a true Mendelian segregation occurs when they breed together. In that case the origin of the rare intermediate forms may be due to incomplete segregation or they may be simply variations of the white form. It is a pure assumption that they are of hybrid origin, hence I think the name *sacra* should be retained.

Anseriformes.

ANATIDÆ.

CHENOPIS ATRATA (*Latham*). Black Swan.

I am informed by Mr. O. Lipfert that a specimen was shot on Gun Island in 1894. It is distinctly surprising to find that this bird flies so far out to sea, especially as the islands do not afford lakes of the kind usually frequented by swans.

[VIRAGO CASTANEA (*Eyton*). Green-headed Teal.

Campbell states that this species occurs in the Wallaby Islands. In view of the confusion between this species and *V. gibberifrons*, and the absence of any specimens, the record requires confirmation.]

Pelecaniformes.

PHALACROCORACIDÆ.

HYPOLEUCUS VARIUS PERTHI, *Mathews*. Pied Cormorant.

These birds are found everywhere round the islands. We only found one colony nesting on West Wallaby Island, where they were in company with Caspian and Crested Terns, and Silver and Pacific Gulls. The nests contained fresh eggs, and when the birds flew off at our approach the Silver Gulls seized the opportunity to feed upon the eggs of their more timid neighbours.

On an islet off Rat Island, we found the nests of an old colony not being used that year. On a little island at the western side of the lagoon, south of the Wallaby Group, we found a number of eggs lying about among the bushes. Cormorants were sitting on the shore on this islet, but they were evidently not nesting there, as there were no nests and the eggs were on or under the bushes promiscuously. Mr. Lipfert obtained eggs on Middle Island in 1894.

PHÆTHONTIDÆ.

SCÆOPHÆTHON RUBRICAUDA WESTRALIS, *Mathews*. Red-tailed Tropic Bird.

A pair of these birds with their single egg, obtained by Mr. Lipfert on Rat Island in November 1894, are in the W.A. Museum.

Subsequently Beddoes wrote to Campbell (10) that he had "found Tropic Bird nesting on Pelsart Island, month February, two eggs, both hard-set. Following February two nests, same kind, were taken on Rat Island; two eggs in each." Mathews, in commenting upon this record, remarks that one egg is the usual clutch, and it seems to me probable that the late Mr. Beddoes made some mistake in the matter.

[LEPTOPHÆTHON LEPTURUS DOROTHEÆ, *Mathews.* White-tailed Tropic Bird.

Recorded by Campbell as an occasional visitor, but he does not state that he saw the species himself nor on what evidence he relied. As there is no other record of the species on the west coast of Australia it requires substantiation.]

PELECANIDÆ.

CATOPTROPELECANUS CONSPICILLATUS (*Temm. & Laug.*). Australian Pelican.

Small parties of these birds were seen on West Wallaby Island, opposite Pelican Island, as well as on Rat Island. We found no evidence that they were or had been nesting, though I specially visited the small island known as Pelican Island, as its name and the presence of pelicans in the vicinity suggested that it might be their stronghold.

Campbell states that they have been known to nest on Pigeon Island, whilst Gibson was told that they nested on West Wallaby Island, appropriating the nest of the Pied Cormorant in which to lay their eggs. Both state that the breeding-season is early (Sept., Oct.).

Falconiformes.

AQUILIDÆ.

CUNCUMA LEUCOGASTER (*Gmelin*). White-bellied Sea-Eagle.

These birds were met with on North Island and all of the southern groups. Their nests were found on several of the small islets in the Wallaby Group, but the young had already flown. Campbell states that they lay in September. Judging from the remains met with round the nests, they feed chiefly on the larger lizards and on Mutton-birds and Terns.

PANDIONIDÆ.

PANDION HALIAËTUS CRISTATUS (*Vieillot*). Osprey.

Much more numerous than the Sea-Eagle, especially on Pelsart Island. Their nests were found on all the groups, generally on small islets. On Pelsart Island, where they nest on the island itself, three nests were found, in each of which was a fully-fledged young bird. Though these were apparently able to fly they did not attempt to do so, but either lay flat in the nest or adopted a threatening attitude with their wings raised and feathers spread. The old birds, meanwhile, circled round high in the air uttering shrill cries.

MAMMALIA.

Carnivora Pinnipedia. OTARIIDÆ.

EUMETOPIAS ALBICOLLIS (*Péron*). White-necked Hair-Seal.

[*Otaria albicollis*, Péron, Voyage de Découvertes aux Terres Australes, vol. ii. p. 118 (1816); J. W. Clark, P. Z. S. 1875.
Arctocephalus lobatus, Gray, Spicilegia Zool., part i. 1828; Gray, Cat. of Seals and Whales, 1866; Gould, Mammals of Australia, vol. iii. pl. xlix.
Otaria australis, Quoy & Gaimard, Voyage de l'Astrolabe, Zool. vol. i. 1830.
Arctocephalus australis, Gray, Cat. of Seals and Whales, 1866.
Zalophus lobatus, Ogilby, Cat. of Australian Mammals, 1892; Lucas and Le Souef, Animals of Australia, 1909.]

Hair-Seals were noted on the group by Stokes; and Gilbert secured specimens which were figured by Gould in his 'Mammals of Australia,' as well as writing an account of their habits. They were evidently very plentiful on the Abrolhos at that time—at any rate, in the breeding-season. Nowadays only a few individuals are to be seen there, as on most other parts of the West Australian coast.

I have given a full synonymy of this species, as, though Gould expressly states that he was not sure of the proper name to use for his Abrolhos specimens, he was, nevertheless, followed by Ogilby and by Lucas and Le Souef, the only recent writers, so far as I am aware, who have mentioned the species. I had reached the conclusion that Péron's name should be used before I read the paper by J. W. Clark, and was confirmed in my view by finding that he had reached the same conclusion in 1875.

Cetacea. BALÆNIDÆ.

MEGAPTERA LONGIMANA, *Rud.* Humpback Whale. Portions of the skeleton of a whale of this species were lying about on the shore of Pelsart Island. In Oct. 1914, when travelling down the coast on the ss. 'Minderoo,' I saw a number of Humpbacks in the neighbourhood of the Abrolhos. Prof. Dakin tells me that some came into Whale Bay in the Pelsart Group during his visit in 1915—apparently, as we were told by the fishermen, to scrape themselves on the rocks.

DELPHINIDÆ.

[SOTALIA GADAMU (*Owen*). Gadamu Dolphin. This appears to be the common "Porpoise" of the West Australian coast, and I presume that the specimens seen at the Abrolhos belong to this species, but there is at present no definite specimen from the group to determine the point.]

REPTILIA.

Chelonia.

CHELONIIDÆ.

CHELONIA MYDAS, *Linn.* Green Turtle.

This species visits North Island and West Wallaby Island, but we were not fortunate enough to see any *.

It is curious that no species of Sea-Snake has yet been recorded from the Abrolhos, as several species occur farther south on the mainland.

PISCES.

A considerable number of small collections of fish have been made at the Abrolhos from time to time. Some coloured drawings were made by Lieut. Emery, one of the officers of H.M.S. 'Beagle' in 1840, and are referred to by Richardson (11, 12), and it is possible that specimens were also obtained. Richardson (12) also refers to specimens collected by Gilbert in 1842, and Ogilby in 1899 described (13) some fish collected at the Abrolhos by Mr. A. M. Lea.

Most of the records in the following list, however, are based on specimens in the Western Australian Museum. Of these some were collected by Saville Kent, some were presented by Mr. F. C. Broadhurst, others were collected by Lipfert in 1894 and 1897, and Conigrave in 1907; whilst, finally, the specimens obtained on the two Percy Sladen Trust Expeditions have been added.

Unless otherwise stated the reason for inclusion in the following list is the presence of a specimen in the W.A. Museum:—

Pleurotremata. GALEORHINIDÆ.

GALEORHINUS ANTARCTICUS (*Günth.*). Gummy Shark. Two specimens caught off the north end of Pelsart Island in 1913.

HETERODONTIDÆ.

HETERODONTUS PHILIPPI, *Bloch & Schneider.* Bull-head or Port-Jackson Shark. Several fine specimens caught at North Island in 1913.

Hypotremata. RHINOBATIDÆ.

RHINOBATUS BANKSII, *Müller & Henle.* Shovel-nosed Ray.

Isospondyli. CLUPEIDÆ.

CLUPANODON NEOPILCHARDUS (*Steind.*). Australian Pilchard.

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* [They were seen by me on the occasion of the Expedition of 1915.—W. J. DAKIN.]

Gonorhynchidæ.

Gonorhynchus greyi, *Rich.* Beaked Salmon or Rat-fish.

Ostariophysi. Ariidæ.

[Galeichthys thalassinus, *Rüpp.* Salmon Cat-fish. A poor specimen, probably of this species.]

Plotosidæ.

Cnidoglanis megastomus (*Rich.*). Estuary Cobbler. Young specimens obtained in 1915.

Apodes. Murænidæ.

Lycodontis woodwardi (*McCulloch*). The type of this species was from the Abrolhos (see 'Records of W.A. Museum,' vol. i. p. 80), and to it McCulloch assigns the specimen from the Abrolhos referred by Richardson (12) to *Muræna nubila*. A third, very young, specimen was obtained by Prof. Dakin in 1915.

Synentognathi. Hemirhamphidæ.

Hyporhamphus intermedius (*Cant.*). Sea-Garfish.

Percesoces. Sphyrænidæ.

Sphyræna obtusata, *Cuv. & Val.* Sea-Pike.

Berycomorphi. Berycidæ.

Trachichthodes affinis (*Günth.*). Nannygai or Red Snapper.

Percoidea. Serranidæ.

Therapon humeralis, *Ogilby*. The type came from Pelsart Island, and the species has not been obtained except in the Abrolhos group.

Acanthistius serratus, *Cuv. & Val.* Wirrah.

Epinephelus merra, *Bloch*.

Epinephelus fasciatus (*Forsk.*).

Epinephelides leai, *Ogilby*. The type was from Pelsart Island. It would appear rather doubtful whether the species is really distinct from *E. armatus* (Cast.).

Colpognathus dentex, *Cuv. & Val.*

Hypoplectrodes nigrorubrum, *Cuv. & Val.*

Dampieria lineata, *Cast.*

PLESIOPIDÆ.

Paraplesiops meleagris, *Peters.* A small specimen obtained in 1915.

CHILODIPTERIDÆ.

Amia rueppelli (*Günth.*). Gobble-guts.

SILLAGINIDÆ.

Sillago bassensis, *Cuv. & Val.* School Whiting.

CARANGIDÆ.

Caranx georgianus, *Cuv. & Val.* Skipjack.

Trachurus declivis, *Jenyns.* Horse-Mackerel.

CENTROPOMIDÆ.

Glaucosoma hebraicum, *Rich.* Jew-fish. The type of this species was from Abrolhos. Several were obtained by us. It is the best food-fish found in the group.

Lates calcarifer, *Bloch.* Giant Perch.

LUTIANIDÆ.

Lutianus chrysotænia, *Bleek.*

NEMIPTERIDÆ.

Scolopsis bimaculatus, *Rüpp.*

LETHRINIDÆ.

Lethrinus opercularis, *Cuv. & Val.*

Pentapus vitta, *Cuv. & Val.* Butter-fish. Obtained by us at North Island.

SPARIDÆ.

Pagrosomus auratus (*Forst.*). Schnapper. The chief food-fish of the group; it is stated to be much less plentiful than was formerly the case.

Sparus sarba, *Forsk.* Silver Bream.

SCORPIDIDÆ.

Neatypus obliquus, *Waite.* The type was from the Abrolhos (see Records of Austral. Mus. vi. p. 64); a second specimen from off Geraldton was presented to the W.A. Museum by Prof. Dakin in 1918.

KYPHOSIDÆ.

Kyphosus sydneyanus, *Günth.* Buffalo-Bream.

GIRELLIDÆ.

Tephræops tephræops (*Rich.*). Buffalo-Bream.

ENOPLOSIDÆ.

Enoplosus armatus (*Shaw*). Old-Wife.

CHÆTODONTIDÆ.

Microcanthus strigatus (*Cuv. & Val.*). Footballer.

CHIRONEMIDÆ.

Threpterius maculosus, *Rich.* Spotted Kelp-fish.

CHILODACTYLIDÆ.

Goniistius gibbosus, *Rich.* Magpie-Perch.

Dactylophora nigricans, *Rich.* Dusky Morwong

POMACENTRIDÆ.

Hypsipops microlepis, *Gunth.*

LABRIDÆ.

Pseudolabrus parilus (*Rich.*).

Lepidaplois vulpinus (*Rich.*).

Achærodus gouldi (*Rich.*). Blue Groper. We obtained several of these fish; they are very good eating when fresh.

Coris auricularis, *Cuv. & Val.* Parrot-fish. Probably the commonest fish of the group. Extremely variable in colour, but the dark tip to the operculum is characteristic. Lieut. Emery made drawings of two colour-varieties in 1840.

Ophthalmolepis lineolatus, *Cuv. & Val.* Rainbow-fish.

Thalassoma lunare (*Linn.*). Crescent-tail.

Thalassoma aneitense, *Gunth.*

These two species of *Thalassoma* seem always to occur together, and it seems to me probable that they are the two sexes of the same species.

ODACIDÆ.

Odax richardsoni, *Günth.* Weedie or Rock-Whiting.

Olisthops cyanomelas, *Rich.* Herring-Kale.

SCARIDÆ.

HETEROSCARUS FILAMENTOSUS, *Cast.*

PSEUDOSCARUS GMYNOGNATHUS, *Bleek* Recorded from Pelsart Island by Ogilby.

Gobioidea. GOBIIDÆ.

CALLOGOBIUS MUCOSUS (*Gunth.*). Obtained in 1915.

Several other species of Goby have been obtained, but have not been identified.

Blennioidea. BLENNIIDÆ.

BLENNIUS TASMANIANUS, *Rich.* Obtained at Sandy Island in 1913.

Other Blennies have been obtained, but not identified.

CONGROGADIDÆ.

CONGROGADUS SUBDUCENS, *Rich.*

Scorpænoidea. SCORPÆNIDÆ.

SYNANCEJA HORRIDA (*Linn.*). Devil-fish.

NEOSEBASTES PANDA (*Rich.*). This species was founded on a drawing made by Lieut Emery at the Abrolhos in 1840. It is also in the W.A. Museum collection.

SCORPÆNA SUMPTUOSA, *Cast.*

PLATYCEPHALIDÆ.

PLATYCEPHALUS BASSENSIS, *Cuv. & Val.* Flathead.

TRIGLIDÆ.

CHELIDONICHTHYS KUMU, *Less & Garn.* Gurnard.

Plectognathi. BALISTIDÆ.

MONACANTHUS CHINENSIS, *Bloch.* Recorded from the Abrolhos by Richardson. A specimen was obtained by Prof. Dakin in 1915.

MONACANTHUS MEGALURUS, *Rich.*

CANTHERINES GRANULATUS (*Shaw*).

CANTHERINES HIPPOCREPIS (*Quoy & Gaim.*).

CHÆTODERMIS MACCULLOCHI, *Waite.* The type-specimen came from the Abrolhos (see Records of Austral. Museum, vi. p. 81). It has not since been met with.

OSTRACIONTIDÆ.

ANOPLOCAPROS LENTICULARIS, *Rich.*

TETRODONTIDÆ.

SPHEROIDES PLEUROGRAMMA, *Regan.* Blow-fish

Pediculati. BATRACHIDÆ.

CORYZICHTHYS DIEMENSIS (*Rich.*). Recorded from the Abrolhos by Richardson. There is a specimen in the W.A. Museum.

SUMMARY.

The marine fauna of the Abrolhos Islands was stated by Saville Kent (14) to be a remarkable mixture of temperate and tropical forms Apart from the corals, which are outside the scope of the present paper, he specially instanced the fish, many of which he stated were common to the Abrolhos and the Barrier Reef and Torres Straits. It will be worth while therefore to examine how far his statement is borne out by the distribution of the marine vertebrates recorded in the present paper.

SEA-BIRDS.—The 36 species of sea-birds which occur on the group may be divided into the following groups. *Summer visitors*—11: wading birds from the Northern Hemisphere, all of which travel farther down the coast than the Abrolhos. *Winter visitors*—2: the Yellow-nosed Albatross has been recorded from as far north as Point Cloates, the Giant Petrel has not been met with north of the Abrolhos. The breeding-places of both are unknown, but are doubtless much farther south. Other southern sea-birds probably occur about the Abrolhos in winter, but almost all the collecting done on the group has been carried out in summer. *Casual visitor*—1: the Black Swan.

The remaining 22 species all breed on the group. Of these 12 are forms found breeding in other localities along the west coast, both north and south of the Abrolhos. Four are not known to breed farther north than the Abrolhos, viz., *Pelagodroma marina dulciæ*, *Puffinus assimilis tunneyi*, *Sternula nereis horni*, and *Gabianus pacificus georgii*. Five are not known to breed farther south than the Abrolhos, viz., *Sterna dougalli gracilis*, *Onychoprion fuscata serrata*, *Anous stolidus gilberti*, *Hæmatopus ostralegus picatus*, and *Scæophaethon rubricauda westralis*. The Abrolhos form of the Lesser Noddy, *Megalopterus tenuirostris melanops*, is not known to breed anywhere else, but as its near ally *M. tenuirostris tenuirostris* breeds in the Seychelles it may be accounted a northern form.

Judging from the sea-birds, therefore, we may conclude that there is a distinct admixture of northern and southern forms, and the three most plentiful species—the Sooty Tern, Noddy, and Lesser Noddy—are all forms which are specially characteristic of tropical islands.

MARINE MAMMALS.—No conclusions can be drawn from the presence of the Seal, as it is, or was, found all round the western half of the continent.

REPTILES.—The Green Turtle, plentiful in the north-west, has not been recorded from farther south than the Abrolhos.

FISH.—The fish-fauna of the north-west coast of Australia is still too little known to allow of a very complete comparison of the northern and southern forms found at the Abrolhos. Sixty-seven species are recorded from the group, of which 5 are not at present known from any other locality, and 4 more do not appear to have been found on the west coast of the mainland. Of the remaining 58, 14 are found generally along the coast-line, 34 do not appear to have been found farther north than the Abrolhos, and 10 are not known from farther south. Of these 10 species, two, *Epinephelus merra* and *Lethrinus opercularis*, have been obtained as far south as New South Wales on the east coast of Australia, so that their most southerly record on the west coast is not remarkable. The remaining 8 northern forms are as follows:—*Lates calcarifer* (N. Australia to India), *Lutianus chrysotænia* (N.W. Australia through Malay Archipelago to Nicobar Islands), *Scolopsis bimaculatus* (N. Australia to China, India, and Red Sea), *Thalassoma lunare*, and *T. aneitense* (N. Hebrides, Norfolk I., and Lord Howe I. to N.W. Australia), *Congrogadus subducens* (N.W. and N. Australia), *Synanceja horrida* (N. Australia to India), *Coryzichthys diemensis* (N.W. and N. Australia).

These 8 species certainly appear to range further south on the west coast of Australia than they do on the east, but there is no good evidence that they occur much further south on the Abrolhos than they do on the mainland. From the next area northward of whose fish anything is known, Shark's Bay, at least 4 of these species have been obtained, viz., *Lutianus chrysotænia*, *Thalassoma lunare* and *T. aneitense*, and *Synanceja horrida*.

It will be worth while to quote here Saville Kent's summary for contrast with the foregoing facts. He states (14)—"The fish fauna of Houtman's Abrolhos was found, as might be anticipated in virtue of its essentially migratory constituents and its proximity to areas of relatively cool water, an interesting admixture of both tropical and temperate species. Conspicuous among the fishes indigenous to the temperate Australian sea-board may be mentioned such species as the Schnapper (*Pagrus major*), the Sergeant Baker (*Aulopus purpurissatus*), Australian Whiting (*Sillago ciliata*), Yellow-tail (*Seriola gigas*), and a species of what in the Sydney market would be designated a Morwong (*Chilodactylus*). Characteristic tropical fish were, on the other hand, specially represented by innumerable varieties of Parrot-fishes, Labridæ and Scaridæ. Many of these, it is interesting to observe, such as species of *Julis* and *Pseudoscarus*, had not been met with by the writer farther north on the Western Australian coast, but were familiar to him, as in the case of the Holothuridæ, as inhabitants of Torres Straits and the Queensland Great Barrier region. Such species, again, as *Platax orbicularis* and *Mesoprion Johni*, the Golden Schnapper of Thursday Island, Torres Straits, may be mentioned among the essentially tropical forms that were found frequenting the Abrolhos reefs."

We may, perhaps, suggest that the "innumerable varieties of Parrot-fishes" were chiefly forms of *Coris auricularis*, which, as already mentioned, is the commonest fish and is very variable in colour; the record of *Platax orbicularis* may refer to *P. teira*, which has been found on the west coast as far south as Fremantle, whilst *Lutianus chrysotænia* may have been mistaken by Saville Kent for *L.* (*Mesoprion*) *johni*. Otherwise, it would be strange if the few species mentioned by him in support of his statement had none of them been obtained by anyone else.

To the writer it would seem more remarkable that the fish-fauna of the Houtman's Abrolhos coral-reefs should consist mainly of species characteristic of the southern coast of Australia, than that a few of the tropical species associated with coral-reefs further north should be found there.

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Annélides Polychètes de l'Archipel Houtman Abrolhos (Australie Occidentale) recueillies par M. le Prof. W. J. Dakin, F.L.S.* Par PIERRE FAUVEL, Professeur à l'Université catholique d'Angers. (Communiqué par le Professeur W. J. DAKIN, D.Sc., F.L.S.)

(Avec 2 figures dans le texte.)

[Lu le 17 mars, 1921.]

L'ARCHIPEL d'îles coralliennes désigné sous le nom de Houtman Abrolhos est situé entre 28° 15′ et 29° de latitude sud. Bien qu'il ne soit éloigné que d'une quarantaine de milles de la côte occidentale de l'Australie, il semble jouir d'un climat notablement plus chaud que le continent voisin à la même latitude.

Tout au moins, la température de la mer y est-elle de quelques degrés plus élevée.

Le phenomène semble avoir pour cause une pointe méridionale formée par un courant chaud de l'Océan Indien. Quoi qu'il en soit, les conditions de la vie marine doivent s'y rapprocher singulièrement de celles que l'on rencontre dans la zone des tropiques, aussi les coraux y prospèrent et ce petit archipel est probablement le groupe d'attolls le plus méridional connu.

Dans une note préliminaire fort intéressante, M. le Prof. Dakin (1917) a exposé et discuté en détail cette situation exceptionnelle qui l'a engage à entreprendre l'exploration rationnelle des Houtman Abrolhos, principalement au point de vue faunique.

Il était, en effet, intéressant de se rendre compte dans quelles proportions les espèces tropicales et les espèces méridionales pouvaient s'y trouver mélangées.

M. le Prof. Dakin ayant eu l'amabilité de me confier la détermination des Annélides Polychètes recueillies dans cette expédition, je pourrai apporter une modeste contribution à cette étude de zoogéographie.

A l'exception d'une *Arenicola cristata* et de quelques *Armandia lanceolata* et *Eunice Siciliensis*, trouvées dans l'estomac de poissons pêchés dans l'estuaire de Swan River, près de Perth, toutes les espèces étudiées ici proviennent de l'archipel des Abrolhos.

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* [The Percy Sladen Trust Expeditions to the Abrolhos Islands.]

Huit familles seulement sont représentées par 15 genres et les 21 espèces suivantes, dont 19 des Abrolhos :—

APHRODITIENS.
Lepidonotus oculatus, Baird.
Lepidonotus cristatus, Grube.
Lepidonotus carinulatus, Grube.
Lepidonotus acantholepis, Grube.
Euthalenessa djiboutiensis, Gravier.

AMPHINOMIENS.
Chloeia flava (Pallas).
Notopygos hispidus, Potts.
Eurythoe complanata (Pallas).

HÉSIONIENS.
Hesione pantherina, Risso.

NÉRÉIDIENS.
Nereis denhamensis, Augener.
Pseudonereis anomala, Gravier.
Platynereis dumerilii, Aud. & Edw.

EUNICIENS.
(?) *Eunice tentaculata*, Quatrefages.
Eunice siciliensis, Grube.
Eunice antennata, Savigny.
Eunice australis, Quatrefages.
Lysidice collaris, Grube.

OPHÉLIENS.
Armandia lanceolata, Willey.
Polyophthalmus pictus, Dujardin.

ARÉNICOLIENS.
Arenicola cristata, Stimpson.

SERPULIENS.
Protula bispiralis (Savigny).

La première remarque qui s'impose est l'absence totale des Polychètes du sable et de la vase (l'*Arenicola cristata* et les *Armandia lanceolata* ne venant pas des Abrolhos). Les Sédentaires ne sont représentées que par le *Polyophthalmus pictus* et un individu de la rare *Protula bispiralis* qui semble n'avoir été observée qu'une seule fois, par Ehlers, depuis Savigny. Ce sont les Aphroditiens et les Euniciens qui dominent de beaucoup, avec les Amphinomiens et quelques Néréidiens.

Nous avons donc là une faunule d'Annélides rampant sur les pierres et les Polypiers. La faune des fentes vaseuses des rochers et des cavités des Madrépores n'est guère représentée que par quelques Eunices.

Il serait imprudent d'étayer de vastes considérations théoriques sur un aussi petit nombre d'espèces correspondant seulement à un habitat restreint de la faune des Polychètes.

L'examen de cette petite collection peut suggérer néanmoins quelques reflexions.

Nous remarquerons d'abord que trois de ces espèces—*Lepidonotus oculatus*, *Nereis denhamensis* et *Eunice tentaculata*—n'ont encore été signalées, jusqu'ici, qu'en Australie, sur les côtes sud et sud-ouest.

Les 18 autres espèces appartiennent à la zone intertropicale. Parmi elles, les 5 suivantes—*Lepidonotus cristatus*, *L. carinulatus*, *L. acantholepis*, *Euthalenessa djiboutiensis* et *Pseudonereis anomala*—habitent les régions les plus chaudes de l'Océan Indien, Mer Rouge, Golfe Persique, Ceylan, par exemple, et n'ont pas encore été signalées en Australie.

Les 13 suivantes—*Chloeia flava*, *Notopygos hispidus*, *Eurythoë complanata*, *Hesione pantherina*, *Platynereis dumerilii*, *Eunice siciliensis*, *E. antennata*, *E. australis*, *Lysidice collaris*, *Armandia lanceolata*, *Polyophthalmus pictus*, *Arenicola cristata* et *Protula bispiralis*—dépassent la zone tropicale au Nord ou au Sud et ont toutes été déjà signalées en Australie et en Nouvelle-Zélande. Parmi elles, *Platynereis Dumerilii*, *Eunice Siciliensis*, *Polyophthalmus pictus* et *Arenicola cristata*, tout à fait cosmopolites, se rencontrent aussi dans la Méditerranée et dans l'Atlantique Nord.

En résumé, sur 19 espèces des Abrolhos, nous en avons 5 spéciales aux régions chaudes de l'Océan Indien, 11 de la zone tropicale, mais la dépassant souvent au Sud et habitant aussi l'Australie méridionale, et 3 seulement propres à cette dernière région. Nous pouvons en conclure, semble-t-il, que la faune des Polychètes des Abrolhos est la même que celle de la plupart des récifs coralliens de l'Océan Indien avec, en outre, quelques espèces jusqu'ici spéciales à l'Australie.

Famille des **APHRODITIENS**, *Savigny*.

Tribu des POLYNOINÉS, *Grube*.

Genre LEPIDONOTUS, *Leach*.

LEPIDONOTUS CRISTATUS, *Grube*.

Lepidonotus cristatus, Gravier (1901), p. 210, pl. 7. fig. 104–110; pl. 9. fig. 136.
„ „ Fauvel (1919), p. 329. (Synonymie.)

Localité.—Wooded Island.

Cette espèce n'est représentée que par la partie antérieure d'un grand spécimen, large de 25 millimètres, soies comprises.

Les trois antennes sont sensiblement égales. Ainsi que l'a fait remarquer Gravier, qui a donné de cette espèce une description très détaillée, les soies ventrales du 2^{e} sétigère diffèrent complètement des suivantes, elles sont longues, fines, presque capillaires et ornées de petites membranes laciniées disposées en spirale.

Les élytres sont ornées chacune d'une grosse crête charnue, plus ou moins nettement bilobée, couverte de petites épines chitineuses coniques. Les élytres sont bordées postérieurement d'un étroit liséré couleur de rouille, et portent une tache de même couleur au-dessus de l'élytrophore. Les différentes papilles de l'élytre sont conformes aux figures de Gravier.

Distribution géographique.—Mer Rouge, Ceylan, Philippines, Iles de la Sonde, Amboine, Abrolhos, Ile Maurice, Zanzibar.

LEPIDONOTUS OCULATUS, *Baird*.

Lepidonotus oculatus, Baird (1865), p. 184.
„ „ Haswell (1883), p. 281.
„ „ Fauvel (1917), p. 171, pl. 4. fig. 20–23.
(?) *Thormora argus* var., Haswell (*non* Quatrefages) (1883), p. 280, pl. 8. fig. 9–11.

Localités.—Dragué entre Wallaby et Rat Island. Dragué à l'extérieur de l'archipel des Wallabys.

Le premier spécimen mesure 37 mill. sur 15 mill., soies comprises; le second atteint 47 mill. sur 15 et il est décoloré à l'exception d'une petite tache brun pâle sur l'élytrophore des élytres postérieures.

Ces spécimens sont bien semblables à ceux des Golfes Saint-Vincent et Spencer, sur la côte Sud de l'Australie.

Distribution géographique.—Australie méridionale, Houtman Abrolhos.

LEPIDONOTUS CARINULATUS, *Grube.*

Lepidonotus carinulatus, Potts (1909), p. 331.
" " Fauvel (1911), p. 367, fig. 1. (Synonymie.)
" " Horst (1917), p. 69, pl. 15. fig. 10.
" " Fauvel (1919), p. 330.

Localité.—Dragué entre les Iles Wallaby et Rat Island.

Il n'a été recueilli qu'un seul spécimen de petite taille dont les élytres sont détachées. Il est tout à fait semblable à ceux de Madagascar que j'ai eu l'occasion d'étudier. La caducité de ses élytres, et ses soies ventrales bidentées, distinguent facilement cette espèce du *Lepidonotus squamatus* auquel elle ressemble beaucoup par ailleurs.

Distribution géographique.—Mer Rouge, Golfe Persique, Ceylan, Philippines, Amboine, Japon, Madagascar, Abrolhos.

LEPIDONOTUS ACANTHOLEPIS, *Grube.*

Lepidonotus acantholepis, Grube (1878), p. 24, pl. 2. fig. 1.
" " Michaelsen (1892), p. 5.
" " Horst (1917), p. 67, pl. 15. fig. 3–4.

Localité.—Récif de Long Island, Pelsart Group.

Cette rare et curieuse espèce est représentée par un seul individu long de 30 mill. et large de 12, soies comprises.

Jusqu'ici, elle semble n'avoir été recueillie qu'aux Philippines par Grube, à Ceylan par Michaelsen et aux Iles de la Sonde par l'expédition du 'Siboga.'

Michaelsen a fait remarquer que les soies ventrales ne sont pas bifurquées, comme l'indiquait Grube, mais, en réalité, trifurquées. Horst a donné une bonne figure de ces soies, qui, vues de profil, rappellent des soies ventrales d'*Hermione*, quand les deux dents inférieures se profilent l'une sur l'autre. Ces deux dents ressemblent aux deux moignons émoussés des soies du premier sétigère des Serpules (Fig. 1, *d*).

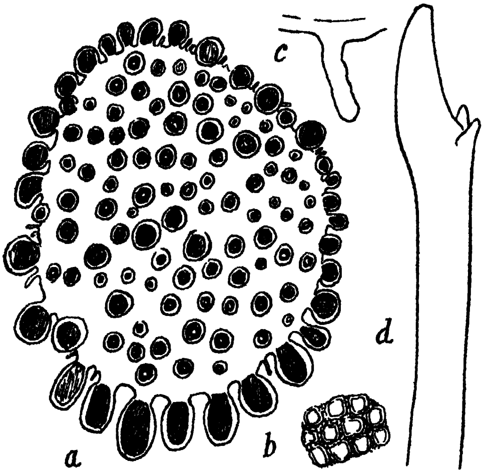
Les soies dorsales, implantées au nombre de 2 à 3 seulement sur un petit mamelon parapodial, sont minces, finement épineuses et terminées en pointe lisse, mousse ou légèrement renflée. Le prostomium, du type *Lepidonotus*, est en grande partie caché par le bord antérieur du premier segment, qui forme un repli nucal très accusé.

L'insertion des antennes est terminale. L'impaire est portée par un volumineux cératophore cylindrique, brun foncé. Elle est notablement plus longue que les antennes latérales.

Les cirres tentaculaires sont accompagnés d'un petit faisceau de soies fines. Tous ces appendices sont annelés de brun et présentent un renflement ovoïde au-dessous de leur extrémité distale effilée.

Les élytres de la première paire sont plus grandes que les suivantes, elles se croisent complètement et cachent la tête. Celles de la deuxième paire se touchent seulement par le bord et celles de la 3^e paire laissent déjà une partie du dos à nu. Ces trois paires sont imbriquées d'avant en arrière, tandis que les suivantes, beaucoup plus petites, laissent entre elles un espace plus grand que leur diamètre, qui ne dépasse pas l'épaisseur du parapode. Les premières élytres sont donc plus grandes et les suivantes plus petites que sur le type de Grube.

FIG. 1.



Lepidonotus acantholepis.—*a*. Èlytre, × 25. *b*. Granulations superficielles d'un tubercule, × 300. *c*. Papille filiforme du bord de l'élytre, × 140. *d*. Soie ventrale, × 100.

Ces élytres sont ovales, ou presque rondes (Fig. 1, *a*). Leur surface est couverte de gros tubercules ovoïdes, à surface finement granuleuse et à contenu brun foncé (Fig. 1, *b*). On remarque, en outre, au bord des élytres, quelques molles papilles cylindriques (Fig. 1, *c*).

L'anus, dorsal, s'ouvre sur l'avant dernier sétigère. Le pygidium est bilobé avec 2 longs urites. Cette espèce présente des affinités avec l'*Hermenia verruculosa*, Grube, qui est un *Lepidonotus*.

Distribution géographique.—Iles de la Sonde, Philippines, Ceylan, Australie occidentale.

Tribu des SIGALIONINÉS, *Grube.*

Genre EUTHALENESSA, *Darboux.*

EUTHALENESSA DJIBOUTIENSIS, *Gravier.*

Thalenessa djiboutiensis, Gravier (1901), p. 231, pl. 7. fig. 114–117.
Euthalenessa djiboutiensis, Fauvel (1918), p. 331; (1919), p. 345.

Localité.—Abrolhos.

L'unique spécimen est tronqué postérieurement et complètement incolore. Il correspond bien à la description détaillée de Gravier et ne diffère pas des spécimens du Golfe Persique que j'ai eu l'occasion d'étudier récemment. Cette espèce se rapproche de la *Thalenessa oculata*, M'Intosh, du Détroit de Bass.

Distribution géographique. — Mer Rouge, Golfe Persique, Houtman Abrolhos.

Famille des **AMPHINOMIENS**, *Savigny.*

Genre EURYTHOË, *Kinberg.*

EURYTHOË COMPLANATA (*Pallas*).

Eurythoë complanata, Augener (1913), p. 87. (Synonymie.)
" " Fauvel (1919), p. 348.
" *alcyonia*, Gravier (1901), p. 248, fig. 257-258.
" *lævisetis*, Fauvel (1914), p. 116, pl. 8, fig. 29–30, 33–37.

Localités.—Récif de Long Island, et à la côte, Pelsart Group. Wooded Island.

Les quelques individus de cette espèce, si répandue dans tous les récifs coralliens, ne présentent rien de particulier à signaler.

Distribution géographique.—Atlantique, Antilles, Guyane, Canaries, Golfe de Guinée, Océan Indien, Mer Rouge, Madagascar, Philippines, Pacifique, Australie, Chili, Iles Gambier.

Genre CHLOEIA, *Savigny.*

CHLOEIA FLAVA (*Pallas*).

Chloeia flava, Fauvel (1917), p. 190. (Synonymie.)

Localité.—King's Sound, Côte Nord-Ouest.

Cette magnifique espèce, dont Milne-Edwards a donné une belle figure en couleurs dans 'Le Règne Animal Illustré,' sous le nom de *Ch. capillata*, a les soies dorsales d'un jaune bronzé à reflets un peu verdâtres, tandis que les ventrales sont d'un blanc albâtre tirant sur le gris. A la face dorsale, chaque segment est orné d'une grosse tache arrondie, pourpre foncé.

Sur ce spécimen, les denticulations de soies en harpon ont complètement disparu, rongées par la formol.

Distribution géographique.—Océan Pacifique, Australie méridionale, Houtman Abrolhos, Océan Indien, Japon.

Genre NOTOPYGOS, *Grube.*

NOTOPYGOS HISPIDUS, *Potts,* var. SERRATUS, *Fauvel.*

Notopygos hispidus, Potts (1909), p. 359, pl. 45. fig. 6-7 ; pl. 46. fig. 3-5.
„ „ Horst (1911), p. 243.
„ „ Fauvel (1917), p. 192 ; (1919), p. 350.
(?) *Notopygos labiatus,* Benham (1915), p. 205.

Localité.—Abrolhos.

Les deux individus de cette espèce, un petit et un autre de taille moyenne, ont les soies dorsales et ventrales également lisses, à l'exception de celles des premiers sétigères qui sont légèrement dentelées *aux deux rames.* Aux derniers sétigères, les soies ventrales sont aussi légèrement dentelées et les dorsales le sont indistinctement. Ils rentrent donc dans la variété *serratus.* Reste à savoir quelle valeur on doit attribuer à ce caractère et si cette espèce n'est pas une simple variété du *N. labiatus,* M'Intosh.

La 1^{re} branchie apparaît au 6^e sétigère et l'anus s'ouvre au 21^e.

Distribution géographique.—Mer Rouge, Océan Indien, Australie méridonale (Houtman Abrolhos).

Famille des **HÉSIONIENS**, *Grube.*

Genre HESIONE, *Savigny.*

HESIONE PANTHERINA, *Risso.*

Hesione pantherina, Saint Joseph (1898), p. 329. (Bibliographie.)
„ „ Gravier (1900), p. 179, pl. 9. fig. 16.
„ „ Fauvel (1911), p. 374, fig. 4 ; (1919), p. 370.
Hesione Ehlersi, Gravier (1900), p. 175, pl. 9. fig. 14-15.
Hesione splendida, Augener (1913), p. 187. (Synonymie.)

Localité.—Dragués à l'extérieur de l'Archipel Wallaby.

Sauf qu'ils sont entièrement décolorés, les deux spécimens des Wallabys ne diffèrent en rien de ceux de la Méditerranée. Mais, ainsi que je l'ai déjà fait remarquer, cette décoloration, dont Gravier faisait un trait distinctif de l'*Hesione Ehlersi,* n'a rien de caractéristique.

Distribution géographique.—Atlantique, Méditerranée, Mer Rouge, Golfe Persique, Ceylan, Philippines, Malaisie, Japon, Australie, Afrique méridionale.

Famille des **NÉRÉIDIENS**, *Quatrefages*.

Genre NEREIS, *Cuvier*.

NEREIS DENHAMENSIS, *Augener*.

Nereis denhamensis, Augener (1913), p. 156, pl. 3. fig. 51.
„ „ Fauvel (1917), p. 204, pl. 6. fig. 45-46.

Localité.—Pelsart Group, à l'intérieur du lagon.

Bien que très macéré, ce spécimen est bien reconnaissable à la disposition de ses paragnathes et à ses soies en serpe homogomphe à la rame dorsale des parapodes postérieurs.

La réduction des groupes vii.-viii. à un seul rang de gros paragnathes, avec quelques petits intercalés, est à peu près le seul caractère distinguant cette espèce, qui semble spéciale à l'Australie, de notre *Nereis pelagica.*

Distribution géographique.—Australie, côtes sud, sud-ouest et nord-ouest (Houtman Abrolhos).

Genre PSEUDONEREIS, *St. Joseph* (*non* Kinberg).

PSEUDONEREIS ANOMALA, *Gravier*.

Pseudonereis anomala, Gravier (1901), p. 191, pl. 11. fig. 50-52.
„ „ Willey (1904), p. 262.
„ „ Fauvel (1911), p. 395; (1919), p. 421.

Localité.—A mer basse, Pelsart Group.

Ce spécimen est malheureusement macéré.

La trompe porte des rangées serrées, pectinées, de petits paragnathes aux groupes de l'anneau maxillaire. Les groupes vii.-viii. forment un rang de paragnathes aplatis alternativement dans le sens transversal et dans le sens longitudinal. Les groupes vi. sont formés d'une rangée de paragnathes coniques, tendant à se dédoubler en deux lignes transversales. Ils sont donc, sous ce rapport, intermédiaires entre la *Ps. anomala* typique et la *P. masalacensis*, Grube, qui est une espèce très voisine.

Distribution géographique.—Mer Rouge, Golfe Persique, Mer d'Oman, Houtman Abrolhos.

Genre PLATYNEREIS, *Kinberg*.

PLATYNEREIS DUMERILII, *Audouin et M.-Edwards*.

Platynereis Dumerilii, Fauvel (1911), p. 397; (1914), p. 193; (1919), p. 421. (Synonymie.)
„ „ Izuka (1912), p. 168, pl. 17. fig. 7-8.
„ *insolita*, Gravier (1901), p. 197. pl. 12. fig. 53.

Localité.—Houtman Abrolhos.

Aucune indication de localité particulière n'accompagnait les deux petits spécimens de cette espèce cosmopolite, si répandue.

Distribution géographique.—Mers Arctiques, Manche, Atlantique, Méditerranée, Océan Indien, Mer Rouge, Golfe Persique, Madagascar, Mer du Japon, Pacifique, Iles Gambier, Australie (Houtman Abrolhos).

Famille des **EUNICIENS**, *Grube*.

Genre EUNICE, *Cuvier*.

(?) EUNICE TENTACULATA, *Quatrefages*.

Eunice tentaculata, Fauvel (1917), p. 209, fig. 17. (Synonymie.)
Eunice pycnobranchiata, M'Intosh (1885), p. 294.
Eunice Elsyi, Baird (1870), p. 344.

Localité.—Abrolhos.

Un fragment postérieur d'une grande *Eunice* aplatie dont les branchies persistent jusqu'aux avant-derniers sétigères me paraît appartenir à cette espèce, très répandue en Australie. Les acicules et soies aciculaires sont noirs, ces dernières sont bidentées.

Distribution géographique.—Australie, Nouvelle-Zélande (Ceylan ?).

EUNICE ANTENNATA (*Savigny*).

Eunice antennata, Crossland (1904), p. 312, pl. 22. fig. 1-7.
„ „ Fauvel (1917), p. 225. (Synonymie.)
„ „ Fauvel (1919), p. 377.
Eunice bassensis, Benham (1915), p. 219, pl. 41. fig. 67-74.

Localite.—Wooded Island.

Sur un individu entier, la 1^re^ branchie se montre au 5^e^ sétigère, comme c'est d'ailleurs le cas le plus fréquent. Les antennes sont moniliformes. Les soies aciculaires sont jaunes et tridentées. Dans la région postérieure, les branchies redeviennent plus longues et plus fournies que dans la région moyenne. C'est d'ailleurs un des traits caractéristiques de cette espèce, bien qu'il ne soit pas toujours aussi marqué.

Distribution géographique.—Mer Rouge, Golfe Persique, Ceylan, Madagascar, Zanzibar, Moluques, Philippines, Détroit de Torres, Détroit de Bass, Australie méridionale, Iles Gambier.

EUNICE AUSTRALIS, *Quatrefages*.

Eunice australis, Fauvel (1917), p. 228. (Bibliographie.)
„ *Murrayi*, M'Intosh (1885), p. 288.
„ *leuconuchalis*, Benham (1900), p. 21 (*fide* Ehlers).

Localité.—Abrolhos.

Cette espèce, représentée par un seul individu, ressemble beaucoup à l'*E. antennata*, mais elle s'en distingue principalement par ses branchies à nombreux filaments qui disparaissent brusquement vers le 38^e^–50^e^ sétigère.

Le soies aciculaires sont jaunes et tridentées. Elles sont souvent au nombre de 3 ou de 4 dans les parapodes postérieurs.

Distribution géographique.—Nouvelle-Zélande, Australie occidentale et méridionale, Zanzibar, Ceylan, Maldives, Cap de Bonne-Espérance.

EUNICE SICILIENSIS, *Grube.*

Eunice siciliensis, Fauvel (1917), p. 231 et (1919) p. 379. (Bibliographie.)
„ *valida*, Gravier (1900), p. 264, pl. 12. fig. 80–82.
„ *leucodon*, Ehlers (1901), p. 128, pl. 16. fig. 1–10.

Localités.—Wooded Island, Lagoon flat ; Pelsart Group, à l'intérieur du Lagon ; Freshwater Bay, 9 Mai, 1914.

L'*Eunice siciliensis* est très répandue dans tous les récifs des mers intertropicales, tout autour du globe. Elle est représentée des Abrolhos par de nombreux fragments souvent dépourvus de tête, mais bien reconnaissables à leurs longues branchies simples et à leurs parapodes à un seul acicule et dépourvus de soies pectinées et de soies aciculaires.

Distribution géographique.—Méditerranée, Atlantique, Antilles, Golfe de Guinée, Détroit de Magellan, Océan Pacifique, Iles Gambier, Hawaï, Australie, Océan Indien, Ceylan, Philippines, Mer Rouge, Golfe Persique.

Genre LYSIDICE, *Savigny.*

LYSIDICE COLLARIS, *Grube.*

Lysidice collaris, Fauvel (1917), p. 236. (Synonymie.)
„ *fallax*, Ehlers (1898), p. 15.

Localités.—Pelsart Group, sur le rivage et à l'intérieur du lagon.

Cette espèce, très voisine de la *Lysidice ninetta*, dont elle n'est probablement qu'une simple variété, ne s'en distingue que par la forme de ses yeux qui sont réniformes ou semi-lunaires, au lieu d'être ovales.

Distribution géographique.—Mer Rouge, Golfe Persique, Ceylan, Philippines, Japon, Seychelles, Madagascar, Zanzibar, Australie méridionale et occidentale, Samoa, Iles Gambier, Guyane.

Famille des **OPHÉLIENS**, *Grube.*

Genre ARMANDIA, *Filippi.*

ARMANDIA LANCEOLATA, *Willey.*

Armandia lanceolata, Willey (1905), p. 228, pl. 5. fig. 120.
„ „ Fauvel (1917), p. 259 ; (1919) p. 435.

Localité.—Freshwater Bay (côte occidentale d'Australie).

Six spécimens, comptant de 27 à 30 sétigères. Beaucoup de branchies sont tombées et les yeux latéraux ont en grande partie disparu. Le tube anal est caractéristique.

Distribution géographique.—Golfe Persique, Ceylan, Australie.

Genre POLYOPHTHALMUS, *Quatrefages*

POLYOPHTHALMUS PICTUS, *Dujardin.*

Polyophthalmus pictus, Fauvel (1919), p. 437. (Synonymie.)

Localité.—Abrolhos.

Un seul spécimen, encore bien pigmenté, représente cette espèce si cosmopolite et de coloration si variable.

Distribution géographique.—Atlantique, Méditerranée, Mer Rouge, Madagascar, Ceylan, Philippines, Chine, Australie occidentale, Iles Gambier.

Famille des **ARÉNICOLIENS**, *Audouin et M.-Edwards.*

Genre ARENICOLA, *Lamarck.*

ARENICOLA CRISTATA, *Stimpson.*

Arenicola cristata, Ashworth (1912), p. 105, pl. 5. fig. 12, 13; pl. 8. fig. 17; pl. 10. fig. 30; pl. 13. fig. 41, 42. (Bibliographie et Synonymie.)
Arenicola antillensis, Ehlers (1892), *passim.*

Localité.— Canning River, trouvée flottant avec le courant. 18 Février, 1914 (Australie occidentale).

Cet unique représentant de cette belle espèce est d'assez grande taille, mais en très mauvais état. La partie moyenne du corps est tellement macérée qu'il est difficile de compter les segments. Il semble bien exister 17 sétigères, les branchies, qui commencent au 7^{e}, sont du nombre de 11 paires. Elles sont très développées, pennées et réunies à la base par une forte membrane.

Le prostomium, malgré son mauvais état, est encore bien reconnaissable et conforme à la figure d'Ashworth (1912, p. 106, fig. 45).

Les otocystes renferment chacun un gros otolithe sphérique. Les deux sacs diaphragmatiques sont gros et allongés. Les deux cæcums digestifs sont courts, épais, renflés et terminés en pointe mucronée. Les premiers segments de la région caudale ne portent pas les petits processus digitiformes qui semblent spéciaux à la variété américaine.

Ashworth a déjà signalé cette espèce au nord-ouest de l'Australie (Barrow Island).

Distribution géographique.—Atlantique Nord, côtes de l'Amérique, Méditerranée, Océan Indien, Mer Rouge, Australie occidentale, Pacifique, Japon, Californie.

Famille des **SERPULIENS**, *Burmeister*.

Genre PROTULA, *Risso*.

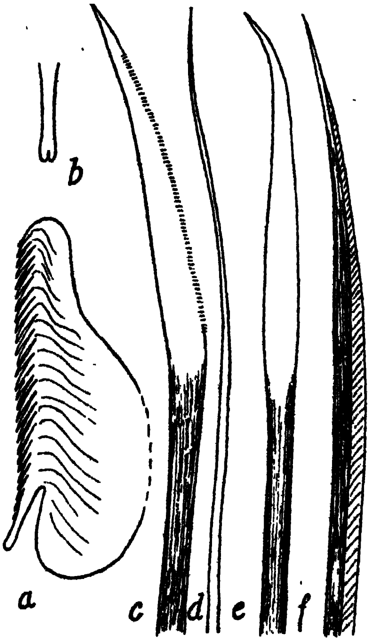
PROTULA BISPIRALIS (*Savigny*).

Serpula bispiralis, Savigny (1820), p. 75.
Protula bispiralis, Quatrefages (1865), tome ii. p. 467.
„ „ Ehlers (1907), p. 31.

Localité.—Abrolhos.

La *Protula bispiralis* a d'abord été décrite par Savigny d'après un individu provenant de la mer des Indes. De Quatrefages en a complété la description d'après le même spécimen. Depuis, elle n'a été mentionnée que par Ehlers qui en a étudié un exemplaire de Nouvelle-Zélande communiqué par Benham. Ehlers ne pense pas que cette espèce puisse être identifiée à l'*Urtica marina americana* de Seba.

FIG. 2.



Protula bispiralis.—*a*. Plaque onciale abdominale, × 300. *b*. Dent inférieure vue de face, × 300. *c*. Soie abdominale, × 140. *d*. Longue soie capillaire abdominale, × 140. *e*. Soie thoracique courte, aplatie, × 140. *f*. Extrémité d'une longue soie thoracique unilimbée, × 140.

Le spécimen des Abrolhos n'est malheureusement pas accompagné de son tube, qu'aucun auteur n'a encore décrit, à ma connaissance. Il mesure 60 mill.

de longueur, y compris le panache branchial de 12 mill., et la région thoracique est large de 10 mill., pieds compris.

Il répond tout à fait à la description de Savigny et de Quatrefages, sauf que les deux volumineux lobes branchiaux ne font que 6 tours de spire, au lieu de 8–9 ; il faut d'ailleurs remarquer qu'il est de taille un peu moindre, le type mesurant 80 mill.

La collerette et la membrane thoracique sont malheureusement déchirées. Le nombre des sétigères thoraciques est de 7. Pas plus qu'Ehlers, je n'y observe d'uncini. Les soies thoraciques sont très nombreuses et de deux sortes : les unes longues, minces, à extrémité très fine légèrement courbée, n'ont qu'un limbe étroit d'un seul côté (Fig. 2, *f*) ; les autres, plus courtes, sont aplaties à l'extrémité et terminées en pointe plus obtuse, arquée (Fig. 2, *e*). Ces soies aplaties sont homologues aux soies d'*Apomatus* de certaines Protules.

Le soies de la région abdominale sont faiblement géniculées, aplaties et finement découpées, sur leur bord convexe, en petites dents coupées carrément (Fig. 2, *c*). D'après de Saint-Joseph, cet aspect serait dû à un plissement du bord mince de la soie. A l'extrémité postérieure, il s'y joint de longues et fines soies capillaires (Fig. 2, *d*). Les uncini abdominaux sont des uncini typiques de *Protula* à nombreuses et fines dents inclinées, à grosse dent inférieure légèrement renflée à l'extrémité qui, vue de face, est légèrement bilobée (Fig. 2, *a*, *b*).

Toutes ces soies sont identiques à celles de la *Protula intestinum*, dont la *P. bispiralis* ne semble se distinguer que par le grand développement de ses lobes branchiaux à tours de spire beaucoup plus nombreux.

Distribution géographique.—Nouvelle-Zélande, mer des Indes, Abrolhos.

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Sherbornina: A new Genus of the Foraminifera from Table Cape, Tasmania.

By FREDERICK CHAPMAN, A.L.S., F.R.M.S., Palæontologist to the National Museum, Melbourne; Hon. Pal. Geol. Surv. Vict.

(PLATE 32.)

[Read 17th March, 1921.]

HISTORY OF THE SPECIMENS.—Early in 1912 I received from the late Mr. R. N. Atkinson *, of Sulphur Creek, N.W. Tasmania, some foraminifera obtained from the Tertiary beds at Table Cape, Wynyard, Tasmania. Recognising their novel character, I put them aside for further investigation, and their description has been still further delayed owing to their requiring to be sliced, a work which had to be postponed on account of the lack of specimens. Mr. Atkinson's father, Mr. E. D. Atkinson, has lately obtained additional specimens, and to him I express my indebtedness.

GEOLOGICAL HORIZON OF THE FORAMINIFERA.—The tests of this type, of which a fair number have been found, have all occurred in the *lower* zone of the Table Cape fossil deposits—the *Crassatellites* Bed. The presence of *Crassatellites oblonga*, T. Woods, sp., and the various volutes determine the age of this bed as Janjukian, which is equivalent to the Middle Tertiary stage of the southern Australian Tertiaries and to the Miocene elsewhere. It lies below the *Turritella* Bed containing *Turritella warburtonensis*, Tate, and the interesting marsupial *Wynyardia bassiana*, Spencer †. That upper bed may be regarded as of Upper Miocene age, since it appears to represent the upper beds at Torquay.

DESCRIPTION :—

Fam. ROTALIIDÆ.

Subfam. ROTALIINÆ.

Genus SHERBORNINA ‡, gen. nov.

Generic Characters.—Test discoidal, moderately thin; median arch concave. Shell built up of a median annular series of chamberlets with a discorbine commencement; the loculi of the annuli widely spaced. External

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* Mr. R. N. Atkinson, after whom I have named the species here described, was a keen and observant collector of the Tertiary fossils of Table Cape. He unfortunately met with an untimely death in 1915, whilst cleaning a military rifle.

† Proc. Zool. Soc. Lond. 1902, pp. 776–794, pls. xlix. & l.

‡ Named in honour of my friend Charles Davies Sherborn, Hon.F.Z.S., A.L.S., who has contributed so much to the literature of this group.

layer formed of small overlapping spatulate chamberlets. The primordial series of about 7 globular to reniform segments, lying in the median system, is discorbine—that is, depressed rotaline. Shell-wall perforated with coarse tubuli.

SHERBORNINA ATKINSONI, gen. et sp. nov. (Plate 32.)

Description of Species.—Test discoidal, thin, complanate. Median area depressed. Texture subtranslucent. Surface faintly showing the annular series of the median layer with the crenulations of the superimposed spatulate chambered layer on either side. A thin median horizontal section shows the commencing series as a discorbine shell of about 7 chambers, followed by 4 imperfectly annulate series, the last two almost completely ring-like and embracing the earlier series. Primordial chamber spherical, measuring 58μ in diameter; chambers 2, 3, and 4 subglobular, 5–9 sublunate, 10 and 11 subannulate and of equal width throughout *. Chamberlets of superficial layers spatulate and squamosely arranged. Diameter of test in holotype 1·9 mm. Thickness of test on periphery ·25 mm. Thickness in median area ·09 mm. Diameter of another specimen 2·3 mm.

Relationships.—This very remarkable form represents for the Rotaliidæ the cycloclypeine annulate multichambered character combined with the lepidocycline spatulate-chambered type found in the Nummulinidæ. But instead of the lepidocycline character being found in the median layer, it is here, strangely enough, found superimposed on the cycloclypeine median series, to form a complex unrecognized in the Orbitoidinæ. This structure of both median and external layers is merely *isomorphous* with the *Cycloclypeus* and *Lepidocyclina* groups, as proved by the commencing series, which is distinctly rotaline, and especially discorbine.

The true relationship of this generic type lies with the planorbuline group, of which a remarkable and allied generic type, *Cycloloculina*, has been described by Messrs. Heron-Allen and Earland †. The present specimens show the same stages of development for the median series of chambers—the discorbine, the pavonine, and the annulate. As in *Cycloloculina*, the tubuli in *Sherbornina* are fairly coarse perforations, and the "deposit of shell-substance between the tubuli" noted by Heron-Allen and Earland in *Cycloloculina* appear to have developed in the present form into small scale-like chamberlets forming the external layers, besides which there is also the crenulate and warty appearance of the surface seen also in *Cycloloculina*. As in *Cycloloculina*, *Sherbornina* has no distinct apertural orifice beyond the openings on the face and periphery leading through the coarse tubuli to the chamberlets.

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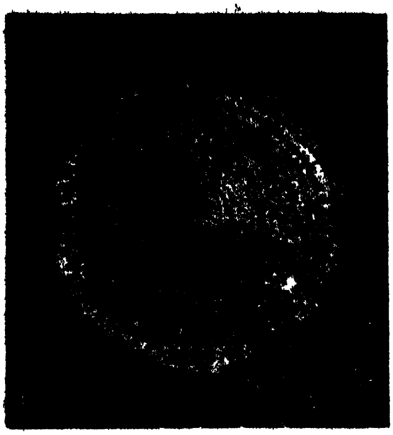
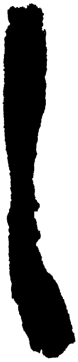
* In this character *Sherbornina atkinsoni* resembles *Cycloloculina annulata* rather than *C. polygyra* of Heron-Allen and Earland. See *postea* and Journ. Roy. Micr. Soc. 1908, pp. 536 and 538.

† Journ. Roy. Micr. Soc. 1908, pp. 529–543, pl. xii.

1 × 21





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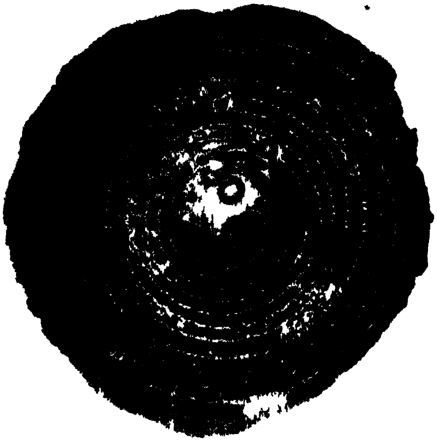
2 × 24



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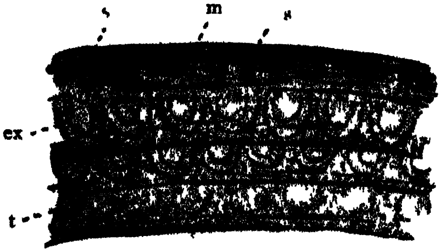

5 × 72

F. C. phot et del ad nat. *Oxford University Press, collo*

SHERBORNINA ATKINSONI F Chapm

Age-relations of Cyclolocnlina *and* Sherbornina.—Messrs. Heron-Allen and Earland obtained their specimens of *Cycloloculina* from amongst derived fossils from Tertiary strata at Selsey. The majority of the fossils found there are, however, of Middle Eocene age, so that the greater chances point to that rock-series as their source of origin. The present Miocene *Sherbornina* seems to be a distinct modification of *Cycloloculina* through the accession of secondary shell-growth and the development of external chamberlets superimposed on the median series.

Occurrence.—Moderately common. In the *Crassatellites* Bed of Wynyardi, Table Cape, Tasmania.

Age.—Miocene or Janjukian.

EXPLANATION OF PLATE 32.

Fig. 1. ***Sherbornina atkinsoni***, gen. et sp. nov. Holotype. Miocene (Janjukian). Table Cape, Tasmania. External surface of test showing annulate plan of growth overlain with tegulous layer of secondary chamberlets. × 21.

Fig. 2. ***S. atkinsoni.*** Horizontal section through median plane, showing the discorbine stage passing into the annulate series. The widely-spaced partitions of the annulate series of chamberlets are seen near the centre and also towards the periphery. The tegulate or overlapping chamberlets of the secondary or external layer are seen halfway to the centre of the test. × 24.

Fig. 3. ***S. atkinsoni.*** Vertical median section through test, showing the relation of the median to the external series of chamberlets. × 34.

Fig. 4. ***S. atkinsoni.*** Structural sketch drawn from micro-section. *m.*, loculi of median series connected by coarse tubules; *ex.*, loculi of external series. × 68.

Fig. 5. ***S. atkinsoni.*** Structural sketch drawn from micro-section. *m.*, loculi of median series; *ex.*, loculi of external series; *s.*, septa of median series; *t.*, shell-wall between median and outer chamberlets, showing coarse perforations. × 72.

On a new Type of Teleostean Cartilaginous Pectoral Girdle found in young Clupeids.

By E. S. Goodrich, F.R.S., Sec.L.S., Prof. of Comparative Embryology in the University of Oxford.

(With 6 Text-figures.)

[Read 18th November, 1920.]

While examining some thionin preparations of the cartilaginous skeleton of a young sprat, *Clupea sprattus*, caught at Plymouth *, I found that the pectoral girdle presented a quite unexpected structure, which seems to have hitherto escaped the notice of anatomists. On investigating the young of *Clupea harengus* and *C. pilchardus* the same peculiar form of girdle was found, and it may be considered as typical of the genus *Clupea*, and possibly may be found to occur in related genera.

In all living Teleostei the endoskeletal girdle, preformed in cartilage in the young, is in a reduced condition relatively to that of the large dermal bones which support it, and consists of right and left halves usually clearly separated in the middle line. Each half is firmly fixed to the cleithrum, and is formed of a short dorsal scapular region and of a generally much larger ventral coracoid region. These are separately ossified, and in many lower Teleostei, including the Clupeiformes, there is another ossification in a dorsal mesocoracoid arch, forming an inner buttress to strengthen the girdle near the articulation of the fin.

Although in many Teleosts the coracoids may be quite large, and may extend towards the middle line and meet, ventrally, yet, so far as I know, the left and right halves are always said to remain separate (3). Neither in the well-known monographs of Parker (5) and Gegenbaur (2), nor in the works of Stannius (6) and other authors, is there any mention of a median fusion of either cartilage or bone (the only possible exception I have met is that of two little ventral epicoracoid cartilages, widely separated from the coracoids, described by Parker as partially fused (5)). On the other hand, it is a familiar fact that in the Elasmobranchii and Dipnoi the two halves of the cartilaginous pectoral girdle, originally separate in the embryo, usually become firmly fused below the pericardium (3).

In the young Sprat, Herring, and Pilchard about 20 to 30 mm. in length, the endoskeletal pectoral girdle is in the form of a solid transverse bar of cartilage extending ventrally from side to side below the pericardium (figs. 1, 2, 3, & 5). At this stage the whole girdle consists of two slender dermal cleithra passing dorso-ventrally to meet below, and the cartilaginous

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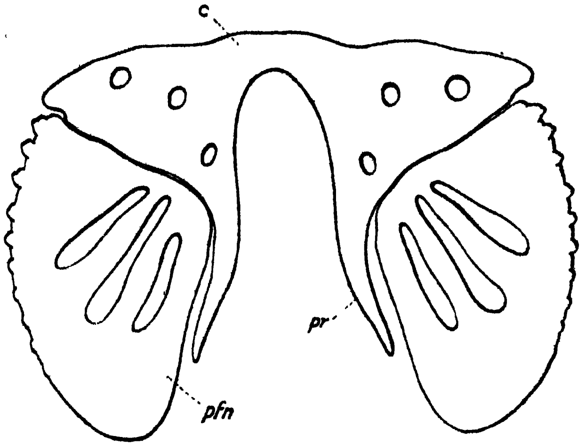
* I am indebted to Miss Lebour for all the material on which this study is founded, and have to thank her for placing it at my disposal. The specimens were preserved in formol.

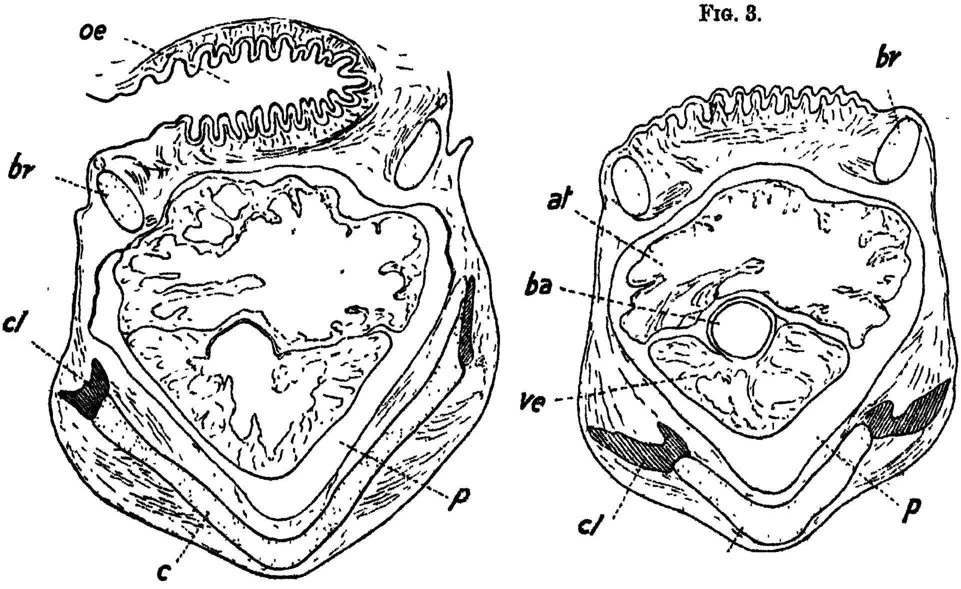
Fig. 1.



Clupea sprattus.
Cartilaginous skeleton of the pectoral fins and girdle.

Fig. 2.

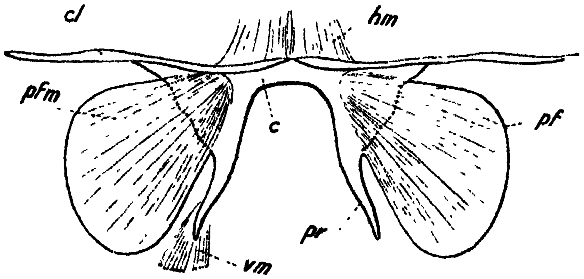
Fig. 3.



Clupea sprattus, 28 mm.
Fig. 2, transverse section showing the pectoral girdle below the pericardium.
Fig. 3, similar section further forward.

ventral bar expanding on either side into a triangular plate perforated by three foramina (fig. 4). These plates and the ventral bar represent the coracoid regions fused. On each side is a small latero-dorsal scapular process projecting in front of the fin-base; while a longer postero-ventral process extends backwards in the body-wall. At a little later stage, shown in fig. 6, the cross-bar becomes bent in the middle to form an acute angle pointing forwards, and at the bend the cartilage becomes absorbed so that the right and left halves soon are separated—a condition which, so far as I have been able to make out, persists in the adult.

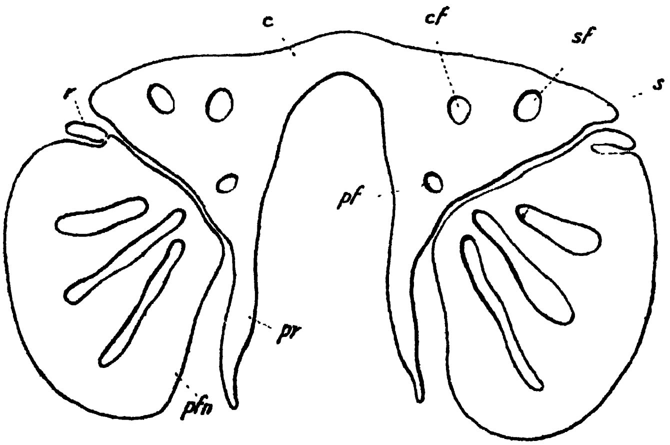
FIG. 4.



Clupea harengus, 30 mm.

Pectoral girdle and fins with muscles attached.

FIG. 5.



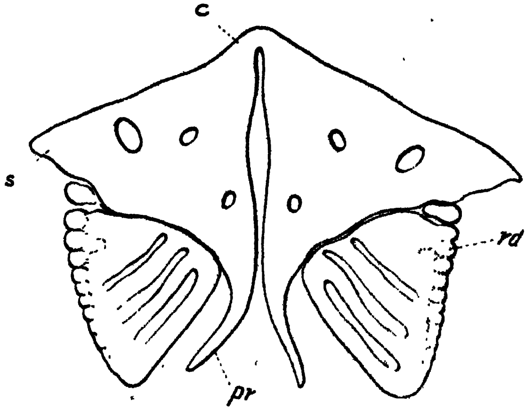
Clupea pilchardus.

Cartilaginous skeleton of the pectoral fins and girdle.

The development of the pectoral girdle in Teleosts has been studied by Swirski (8) and Wiedersheim (10), and has lately been very completely worked out by Swinnerton in *Salmo* and *Gasterosteus* (7), by Derjugin in *Exocœtus* (1), and by Haller and by Vogel in *Salmo* (4 & 9). These authors have ascertained that the endoskeletal girdle and fin-skeleton arise from paired rudiments widely separated. From each rudiment develops a procartilaginous plate in which become differentiated the fin radials and the girdle. The coracoid process of the latter grows downwards and forwards, and may even meet its fellow of the opposite side, without, however, fusing with it. A posterior process grows out behind, and subsequently dwindles and disappears in the adult. In *Clupea*, I find that the girdle arises in just the same way from paired rudiments, and that its subsequent history differs only in the formation of the transverse bar by fusion across the mid-ventral line.

As to what significance should be attached to the peculiar structure of the cartilaginous girdle in Clupeids described above, it would be rash to come to any definite conclusion before the corresponding stages in the development of allied forms have been studied. Two points may, however, be noticed:—(1) that the condition when the two halves form a continuous bar is transitory, the girdle being of paired origin and the halves separating again in later life when the dermal bones become well-developed; (2) that in no other Teleostomes, however primitive, do we find the paired elements of the girdle fused in the middle line. Therefore we can hardly suppose that the cross-bar represents an ancestral condition; rather would we suggest that it may be a specialisation due to the necessity of affording a firm base of support for the large pectoral fins in young Clupeids, which are active swimmers.

FIG. 6.



Clupea sprattus, 36 mm.

Cartilaginous skeleton of the pectoral fins and girdle.

Summary:—In the young of *Clupea sprattus*, *C. harengus*, and *C. pilchardus* about 20 to 30 mm. in length, the right and left coracoid regions fuse to a solid cartilaginous ventral bar, which becomes bent and again subdivided in later stages. This fusion is probably a specialisation to strengthen the support of the pectoral fins before the complete development of the dermal bones of the pectoral girdle.

Reference-letters for Figures 1–6.

at, atrium; *ba*, bulbus arteriosus; *br*, branchial arch; *c*, coracoid region; *cf*, coracoid foramen: *cl*, cleithrum; *hm*, hypoglossal muscles; *œ*, œsophagus; *p*, pericardium; *pf*, postcoracoid foramen; *pfm*, pectoral fin muscles; *pfn*, pectoral fin skeleton; *pr*, posterior process; *r*, radial; *rd*, distal radial cartilage; *s*, scapular process; *sf*, scapular foramen; *ve*, ventricle; *vm*, ventral body-wall muscle.

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[Synonyms and native names are printed in *italics*. A star * denotes the first publication of a name.]

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